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Short Communication

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Generation mean analysis of preferential oviposition behaviour of pink stem borer (*Sesamia inferens*) in maize germplasm

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ABSTRACT

Generation mean analysis of *S. inferens* egg load in maize germplasm was undertaken by involving nine cross combinations; generated between two resistant (DMRE1 & DMRE2) and three susceptible (CM202, CML451, CML287) inbred lines. Significant differences in mean egg load between resistant (8 to 38 eggs/plant) and susceptible (179 to 251 eggs/plant) inbred lines was observed. In F_1 generation, either partial dominant or over dominant towards higher oviposition was observed across all cross combinations except one cross i.e. CML451 X CM202, a cross between two susceptible inbred lines, where lower oviposition in F_1 as compared to parents was observed. The results of gene effects for egg load on plant did not show any specific type of gene effects but showed a mixed type *viz., a, d, i, j, k*. It is highly unlikely that any one kind of gene effects will determine the ovipostion on plants/seedlings.

Keywords: Backcross generations, Generation mean analysis, Genetic variance, Oviposition, Pink stem borer.

The first step while establishing any insect pest-host plant relationship is the preferential oviposition by insect on the desired plants. Studies on oviposition behavior of *Spodoptera frugiperda* have shown that there exists a strong oviposition preference for Bt maize over non-Bt maize (Téllez-Rodríguez *et al.*, 2014). Similarly in one of the previous study, it was found that there was significant differences exist with respect to *Sesamia inferens* Walker egg load between resistant and susceptible inbred lines of maize, which indicates the preferential oviposition behaviour of *S. inferens* for susceptible inbred lines as against the resistant (Sekhar *et al.*, 2009). Therefore, in order to understand the mechanism of resistance an attempt was made to study the genetics of the preferential oviposition behavior of *S. inferens*, the major insect pest of maize in India.

MATERIALS AND METHODS

Two resistant (R) *viz.*, DMR E1 and DMR E2 and three susceptible (S) lines *viz.*, CML 451, CML 287 and CM 202 were used to generate nine F_1 crosses between R × S and S × S inbred lines. The R × S crosses (DMR E1 × CML 451, DMR E1 × CM 202, DMRE1 × CML 287, DMR E2 × CML 451, DMR E2 × CM 202, DMR E2 × CML 287) and S × S crosses (CML 451 × CM 202, CML 451 × CML 287 and CM 202 × CML 287) were advanced by selfing and also backcrossed to both the parents to generate F_2 and backcross generations (BC_1P_1 and BC_1P_2) with both parents respectively.

A total of 54 populations derived from nine crosses with each cross consisting of six generations (Parent 1, Parent 2, F_1, F_2, BC_1P_1 and BC_1P_2) were used for generation mean analysis (GMA) to understand the oviposition behaviour of pink borer in maize. The oviposition behaviour and the distribution of eggs of Pink borer, *Sesamia inferens* Walker within a plant were studied in 2007-08 to 2011-12 by releasing a pair of moths (female: male) on 8-10 old plants at 21±1°C. The data on egg laying (eggs/plant) was recorded four days after release of moths on different plant parts.

RESULTS AND DISCUSSION

The results indicated that moths preferred to lay eggs inside the leaf sheath of the plant and there was significant differences present with respect to egg load between resistant and susceptible plants. The mean number of eggs found on second leaf sheath in the resistant genotypes varied from 8 (DMRE2) to 38 (DMRE1), while among the susceptible genotypes it ranged from 179 (CM202) to 251.5 (CML287). Out of nine F_1 cross combinations, three

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Table 1. Mean number of eggs laid by pink borer in different generations of nine crosses during *rabi* 2011

Egg	DMR E1 X CM202	DMR E1 X CML451	DMRE1 X CML287	DMR E2 X CM202	DMR E2 X CML451	DMR E2 X CML287	CM202 X 287 CML	CML451 X CM202	CML451 X CML287
P_1	38.0±3.2	38.0±3.2	38.0±3.2	8.0±1.6	8.0±1.6	8.0±1.6	179.0±15.2	249.0±20.6	249.0±20.6
P_2	179.0±15.2	249.0±20.6	251.5±20.3	179.0±15.2	249.0±20.6	251.5±20.3	251.5±20.3	179.0±15.2	251.5±20.3
F_1	239.0±32.4	142.0±13.6	166.0±20.1	53.0±6.8	24.0±4.4	54.0±7.8	236.5±26.1	87.5±7.8	346.3±28.4
F_2	35.5±3.9	205.0±33.7	60.5±7.4	500.0±35.6	66.0±11.1	93.0±15.7	437.0±43.8	160.0±20.5	359.5±36.9
BC_1	67.5±17.8	156.5±13.6	54.5±9.8	107.5±16.4	23.0±5.3	53.5±11.1	123.5±15.6	178.5±27.0	155.5±20.6
BC_2	76.0±18.5	246.0±35.5	183.5±31.0	184.0±30.2	35.0±4.3	331.1±45.8	79.1±14.0	181.0±24.2	293.0±37.8

Table 2. Gene effects for number of eggs laid by pink borer through generation means analysis in nine crosses during *rabi* 2011

Egg	DMRE1 X CM202	DMRE1 X CML451	DMRE1 X CML287	DMRE2 X CM202	DMRE2 X CML451	DMRE2 X CML287	CM202 X CML287	CML451 X CM202	CML451 X CML287
M (mean)	-32.42±11.92	142.39±10.03		1500.76±153.68	128.50±10.32		1547.87±180.39	220.12±11.64	791.27±171.56
d (Add)	-70.58±7.71	-104.33±9.99	-108.02±9.69	-85.08±7.47	-120.50±10.32	-123.87±10.15		32.17±12.02	
h (Dom)		257.06±52.61	139.94±10.07	-2555.28±333.44	-280.83±33.86	399.92±53.02	-3132.12±374.70	-129.82±14.57	-1282.10±395.77
i (Add * Add)	141.01±14.10		146.08±9.78	-1407.68±153.88		131.89±10.15	-1342.80±179.98		-541.00±170.95
j (Add * Domt)	124.30±53.56				219.46±24.70	-144.42±65.00	88.80±41.98		-275.00±86.09
l (Dom * Dom)	271.922±42.857	-257.441±55.395		1107.518±183.863	176.32825.902	-345.922±54.72	1820.746±202.489		837.133±235.642

F_1s *viz.*, DMRE1 X CM202 and CML451 X CML287 (towards higher egg load) and CML451 X CM202 (towards lower egg load), have shown over dominance and the rest (DMRE1 X CML451, DMRE1 X CML287, DMRE2 X CM202, DMRE2 X CML451, DMRE2 X CML287, CM202 X CML287) showed partial dominance. A cross between two susceptible parents, CML451 X CM202 has shown low egg load in F_1 (87.5) probably due to presence of gene(s) combination which complement each other to reduce the egg load.

In most of the cross combinations the egg load in F_2 was contrast to what was observed in F_1s suggesting accumulation of either favourable or unfavourable gene(s) combinations due to increased homozygous condition. In general, the parental combinations determined the egg load which indicates that the complementary reaction between different gene(s) combinations and / or genetic background (Table 1).

The gene actions for egg load on plant were also studied (Table 2). It was observed that additive gene action is responsible for reducing the egg load in all cross combinations (DMRE1 X CM202, DMRE1 X CML451, DMRE1 X CML287, DMRE2 X CM202, DMRE2 X CML451, DMRE2 X CML287) where the resistant parent is involved. In addition dominance gene action was also involved in a two cross combinations *viz.*, DMRE2 X CM202, DMRE2 X CML451, where DMRE2, a resistant inbred line was a common parent. Further other type of gene actions like *i* (DMRE2 X CM202, CM202 X CML287, CML451 X CML 287), *j* (DMRE2 X CML287 and CML451 X CML 287) and *l* (DMRE1 X CML451 and DMRE2 X CML287) are also involved to reduce the egg load. However, the result does not indicate any specific type of gene actions across all cross combinations. Thus, it is unlikely that any one kind of gene action determine the egg load on plant/seedlings but, it is a mixed type of gene actions which includes all types of gene actions both positive and negative side and differ depending upon the cross combinations involved.

The mean egg load of *Sesamia inferens* Walker on resistant vis-à-vis susceptible inbred lines of maize indicated the preferential oviposition behaviour of *S. inferens*. However, the genetic study indicated that there are no specific gene effects responsible for the preferential oviposition behaviour of *S. inferens* but the mixed type of gene action.

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Genetic variability, correlation and path coefficient analysis of newly derived S_6 lines of maize (*Zea mays* L.)

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ABSTRACT

The yield is a complex trait, which is highly influenced by the environment and hence indirect selection through component traits would be an advisable strategy to increase the efficiency of selection. Eighty two newly derived S_6 lines of maize were developed from the National Yellow Pool, AICMIP, ARS, Arabhavi and were evaluated in a randomized complete block design with two replications to assess the direct and indirect effects of grain yield among twelve quantitative traits. The traits viz., 100-seed weight, cob length, cob girth, number of rows per cob and number of kernels per row had significant positive phenotypic and genotypic correlation with grain yield. However, path coefficient analysis revealed that 100-seed weight, number of kernel rows per cob, number of kernels per row, cob length, plant height, shelling percentage, cob girth, ear height, days to 75 per cent dry husk and days to 50 per cent silking had direct effect on grain yield, indicating that selection for these characters can help to improve the grain yield in maize. High heritability estimates were detected for most of the traits studied, indicating that the additive genetic variance was the major component of genetic variation in the inheritance of these traits and selection will be effective for improving these traits.

Keywords: Correlation, Genetic variability, Heritability, Path coefficient analysis and S_6 lines

Maize (*Zea mays* L.) is the third most important cereal food crop of the world belonging to the family Poaceae and tribe Maydeae after wheat and rice (Poehlman, 1997). In country like India, rapid growth in population outstrips our grain in cereal production. Increased production of maize and its alternate utilization in food channel can reduce the pressure on wheat, rice and its imports. Now-a-days, maize has also been recognized as an industrial crop because of the diversified products that can be developed like starch, syrup, glucose, gluten and oil. Nearly 49% of the total maize produced is being utilized as a raw material in the poultry feed industry.

The development of new varieties mainly depends on the magnitude of genetic variability in the base material for the desired character. Genetic variability is of great interest to the plant breeder as it plays a vital role in framing successful breeding programme. The knowledge of genetic variability, heritability, genetic advance and relationship between yield and its contributing characters in a given crop is of paramount importance for the success of any plant breeding programme. Yield of corn is complex parameter which is influenced by a number of inter-related traits. The inter-dependence of component characters with yield indicates only the overall relationship. Hence information based on correlation coefficients is only partial, whereas the path coefficient analysis permits the partition of correlation coefficients into direct and indirect effects and gives a more realistic relationship of the characters and helps in identifying the effective components. The present investigations were undertaken to estimate correlations and path coefficients for some morphological, yield and yield component traits of newly derived S_6 lines of maize.

MATERIALS AND METHODS

The germplasm consisted of 82 newly derived S_6 lines of maize tested in randomized complete block design with two replications at AICMIP, Agriculture Research Station, Arabhavi, Gokak taluk, Karnataka during *kharif* 2013. These lines were derived from National Yellow pool. Each genotype was grown in a two rows of 4 m length, spaced 75 cm apart with a 20 cm distance between plants within

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the row. Ten plants were selected randomly in each entry for recording the observations on plant height, ear height, ear length, ear girth, kernel rows/ear, kernels/ row, 100-seed weight, shelling percentage and grain yield/plant while, data related to days to 50 per cent taselling, days to 50 per cent silk emergence and days to 75 per cent dry husk was also recorded on whole plot basis. The mean values were used for statistical analysis. The genetic parameters *viz*., genotypic and phenotypic coefficients of variation were worked out by Burton and Devane (1953) method and broad sense heritability and genetic advance as per cent of mean were studied by Robinson *et al.* (1949). The phenotypic and genotypic correlation coefficients were studied by Johnson *et al.* (1955). Path analysis was carried out using the simple correlation coefficient to know the direct and indirect effects of the yield and its components as suggested by Wright (1921) and illustrated by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Analysis of variance revealed significant differences for 12 quantitative traits (Table 1). Wide difference between PCV and GCV estimates were observed for ear height (5.42), grain yield per hectare (3.85), grain yield per plant (2.75), kernels/row (1.90), kernel rows per cob (1.31), plant height (1.20), cob length (1.01), shelling percentage (0.99) 100-seed weight (0.86), followed by cob girth (0.84) revealing greater role of environment interaction with the genetic factors in the expression of the traits, whereas days to 75% dry husk (0.41), days to 50% silk emergence (0.43) and days to 50% tasseling (0.45) exhibited lower differences indicating more influence of genetic factors in determining variability. Similar results were obtained by Satyanarayana and Saikumar (1996). The grain yield/plant (20.54% and 17.79%), grain yield per hectare (18.86% and 15.01%), ear height (17.25% and 11.83%) and 100-seed weight (12.19% and 11.33%) were observed to possess moderate PCV and GCV estimates (Table 2), indicating that the selection based on these traits would facilitate the successful isolation of desirable genotypes easily.

Table 1. Analysis of variance for 13 characters related to grain yield in maize

Traits	Source of variation		
	Replications (MSS)	Genotypes (MSS)	Error (MSS)
Days to 50 per cent tasseling	0.15	3.18**	0.62
Days to 50 per cent silking	0.49	3.10**	0.65
Days to 75 per cent dry husk	5.13	7.23**	1.51
Plant height (cm)	89.27	463.77**	61.89
Ear height (cm)	66.21	5160.04**	139.08
Cob length (cm)	0.39	5.12**	0.50
Cob girth (cm)	0.22	1.07**	0.17
Number of kernel rows per cob	0.83	1.81**	0.34
Number of kernels per row	2.51	16.57**	3.55
Shelling percentage	0.02	7.00**	3.05
100 seed weight (g)	7.05	30.82**	2.25
Grain yield per plant (g)	5.20	1390.61**	198.71
Grain yield per hectare (q)	0.03	47.88**	10.74

** Significant at 0.01 probability level

Table 2. Mean, range, genetic variability, heritability and genetic advance parameters for grain yield and its component traits in maize

Traits	Mean	Range	PCV (%)	GCV (%)	h^2bs (%)	GAM (%)
Days to 50 per cent tasseling	57.62	55.50 – 60.00	2.39	1.96	67.30	3.31
Days to 50 per cent silking	59.03	56.50 – 61.50	2.32	1.87	65.20	3.11
Days to 75 per cent dry husk	99.01	92.00 – 102.50	2.11	1.70	65.40	2.84
Plant height (cm)	169.92	131.50 – 202.00	9.54	8.34	76.50	15.02
Ear height (cm)	82.99	48.00 – 113.00	17.25	11.83	47.00	16.71
Cob length (cm)	15.45	11.05 – 18.84	10.84	9.83	82.20	18.36
Cob girth (cm)	14.13	11.10 – 15.55	5.58	4.74	72.00	8.28
Number of kernel rows per cob	13.68	11.20 – 16.40	7.56	6.25	68.40	10.65
Number of kernels per row	32.69	24.40 – 38.20	9.70	7.80	64.70	12.93
Shelling percentage	83.76	78.80 – 87.99	2.67	1.68	39.30	2.16
100 seed weight (g)	33.33	25.00 – 44.00	12.19	11.33	86.40	21.71
Grain yield per plant (g)	137.27	58.60 – 212.20	20.54	17.79	75.00	31.73
Grain yield per hectare (q)	28.69	14.17 – 41.78	18.86	15.01	63.40	24.62

PCV – Phenotypic coefficient of variation; GCV – Genotypic coefficient of variation; h^2bs – Heritability in broad sense; GAM – Genetic advance as per cent over mean

In the present study, 100 seed weight (86.40%), cob length (82.20%), plant height (76.50%), grain yield per plant (75.00%), cob girth (72.00%), number of kernel rows per cob (68.40%), days to 50 per cent tasseling (67.30%), days to 75 per cent dry husk (65.40%), days to 50 per cent silking (65.30%), number of kernels per row (64.70%) and grain yield per hectare (63.40%) showed higher heritability, whereas, ear height (47.00%) and shelling percentage (39.30%) showed moderate heritability. Broad sense heritability ranged from 39.30 per cent (shelling percentage) to 86.40 per cent (100 seed weight). Grain yield/plant (31.73%), grain yield per hectare (24.62%) and 100-seed weight (21.71%) showed high GAM combined with high heritability indicating improvement of these traits through *per se* selection and using them in hybrid breeding programme.

The phenotypic and genotypic correlation coefficients among 12 quantitative traits are presented in Table 3. The genotypic correlations in general were higher than the phenotypic correlation, revealing strong inherent relationship among the characters studied. Grain yield showed highly significant positive correlation with plant height (P-0.60, G-0.71) (Swarnalatha Devi and Shaik Mohammad 2001), ear length (P-0.60, G-0.69), ear circumference (P-0.50, G-0.60) (Pradeep Kumar and Satyanarayana, 2001), number of kernel rows per ear (P-0.16, G-0.22), number of kernels per row (P-0.58, G-0.64) (Geetha and Jayaraman 2000), 100-seed weight (P-0.65, G-0.72) (Umakanth and Khan, 2001), shelling percentage (P-0.19, G-0.28) and days to 75% dry husk (P-0.12, G-0.21). A non-significant negative association was observed between grain yield and its component traits such as days to 50 per cent tasseling (P-0.02, G- -0.09) and days to 50 per cent silking (P- -0.06, G- -0.14) (Netaji *et al.*, 2000). The negative correlation of grain yield with days to 50 per cent flowering is very much important for breeder to identify early and late maturing inbreds.

Table 3. Phenotypic and genotypic correlations among different quantitative traits in maize at Arabhavi

Characters		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1: Days to 50% tasselling	P	1.00	0.92**	0.50**	0.10	0.18*	0.04	0.03	0.07	0.03	0.01	0.01	0.02
	G	1.00	0.91**	0.51**	-0.17*	-0.24**	-0.07	-0.01	0.03	-0.17*	0.06	0.01	-0.09
X2: Days to 50% silking	P		1.00	0.51**	0.09	0.22**	0.05	0.03	0.09	0.07	0.06	0.02	-0.06
	G		1.00	0.51**	-0.16*	-0.30*	-0.08	-0.02	0.09	-0.23*	-0.04	-0.02	-0.14
X3: Days to 75% dry husk	P			1.00	0.13	0.03	0.05	0.15*	0.13	0.09	0.09	0.20**	0.12
	G			1.00	0.16*	-0.05	0.06	0.17*	-0.14	0.10	0.18*	0.31**	0.21**
X4: Plant height (cm)	P				1.00	0.61*	0.48**	0.45**	0.11	0.44**	0.04	0.40**	0.60**
	G				1.00	0.64*	0.60**	0.53**	0.17*	0.56**	0.01	0.47**	0.71**
X5: Ear height (cm)	P					1.00	0.33**	0.48**	0.10	0.40**	0.07	0.36**	0.50**
	G					1.00	0.36**	0.55**	0.13	0.46**	0.08	0.40**	0.55**
X6: Cob length (cm)	P						1.00	0.26**	0.11	0.67**	0.01	0.42**	0.60**
	G						1.00	0.33**	-0.10	0.78**	-0.07	0.49**	0.69**
X7: Cob girth (cm)	P							1.00	0.14	0.27**	0.06	0.43**	0.50**
	G							1.00	0.19*	0.31**	-0.07	0.54**	0.60**
X8: No. of rows per cob	P								1.00	0.13	0.03	0.13	0.16*
	G								1.00	-0.12	0.01	-0.17*	0.22**
X9: No. of kernels per row	P									1.00	0.21**	0.27**	0.58**
	G									1.00	0.13	0.32**	0.64**
X10: Shelling percentage	P										1.00	0.01	0.19*
	G										1.00	-0.01	0.28**
X11:100 seed weight (g)	P											1.00	0.65**
	G											1.00	0.72**
X12: Grain yield per plant (g)	P												1.00
	G												1.00

*Significant at 0.05 probability level; **Significant at 0.01 probability level; P: phenotypic correlation; G: genotypic correlation

Sometimes, correlation coefficients give misleading results because the correlation between two variables may be due to third factor. It is therefore necessary to analyze the cause and effect relationship between dependent and independent variables to entangle the nature of relationship between the variables. Path coefficient analysis (Dewey and Lu 1959) furnished a method partitioning the correlation coefficient into direct and indirect effect and provides the information on actual contribution of a trait on the yield.

In the present study, path analysis was used to work out the direct and indirect effects of 11 characters on grain yield presented in Table 4. The traits which not only have high positive correlation but also have high direct effects are expected to be useful as selection criteria in selection programme. Considering this point, 100-seed weight (P-0.44, G-0.47), number of kernels per row (P-0.24, G-0.16), shelling percentage (P-0.12, G-0.28), number of kernel rows per ear (P-0.24, G-0.33), plant height (P-0.15, G-0.12), cob length (P-0.17, G-0.29), cob girth (P-0.09, G-0.12), days to 50 per cent silking (P-0.02, G-0.01) and days to 75 per cent dry husk (P-0.01, G-0.04) had high positive direct effect on grain yield. The results were supported by the earlier findings of Packiaraj (1995) for plant height and 100-seed weight, Manivannan (1998) for number of kernel rows per ear, number of kernels per row, Gautam *et al*. (1999) for ear circumference, Krishan and Natarajan (1995). The residual effects permit precise explanation about the pattern of interaction of other possible components of yield. The genotypic and phenotypic residual effects recorded 0.2488 and 0.5133 respectively; it indicates the characters used in our experiment explain above 50 per cent of variations which may be contributed to higher yields in maize.

It may be concluded that plant height, ear height and all the yield component characters like ear length, ear girth, kernel rows/ear, kernels/row and 100-seed weight appeared to be prominent characters that could be used in selecting inbred lines for hybridization programme,

Table 4. Direct (diagonal) and indirect effects of grain yield component traits on grain yield per plant at phenotypic and genotypic level in maize at Arabhavi

Characters		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1: Days to 50 per cent tasselling	P	-0.03	-0.03	-0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-0.02
	G	-0.11	-0.10	-0.05	0.02	0.03	0.01	0.01	0.01	0.02	-0.01	0.01	-0.09
X2: Days to 50 per cent silking	P	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-0.06
	G	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-0.14
X3: Days to 75 per cent dry husk	P	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.12
	G	0.02	0.02	0.04	0.01	0.01	0.01	0.01	-0.01	0.01	0.01	0.01	0.21
X4: Plant height (cm)	P	-0.02	-0.01	0.02	0.15	0.09	0.07	0.07	0.02	0.07	0.01	0.06	0.60
	G	-0.02	-0.02	0.02	0.12	0.08	0.07	0.06	0.02	0.07	0.01	0.06	0.71
X5: Ear height (cm)	P	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.50
	G	0.01	0.02	0.01	-0.03	-0.05	-0.02	-0.03	-0.01	-0.02	0.01	-0.02	0.55
X6: Cob length (cm)	P	-0.01	-0.01	0.01	0.08	0.06	0.17	0.04	-0.02	0.11	0.01	0.07	0.60
	G	-0.02	-0.02	0.02	0.17	0.10	0.29	0.09	-0.03	0.22	-0.02	0.14	0.69
X7: Cob girth (cm)	P	0.01	0.01	0.01	0.04	0.04	0.02	0.09	0.01	0.02	0.01	0.04	0.50
	G	0.01	0.01	0.02	0.06	0.07	0.04	0.12	0.02	0.04	-0.01	0.07	0.60
X8: No. of rows per cob	P	0.02	0.02	-0.03	0.03	0.03	-0.03	0.03	0.24	-0.03	0.01	-0.03	0.16
	G	0.01	0.03	-0.04	0.06	0.04	-0.03	0.06	0.33	-0.04	0.01	-0.06	0.22
X9: No. of kernels per row	P	-0.01	-0.02	0.02	0.11	0.10	0.16	0.07	-0.03	0.24	0.05	0.07	0.58
	G	-0.03	-0.04	0.02	0.09	0.07	0.12	0.05	-0.02	0.16	0.02	0.05	0.64
X10: Shelling percentage	P	0.01	-0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.12	0.01	0.19
	G	0.02	-0.01	0.05	0.01	0.02	-0.02	-0.02	0.01	0.04	0.28	0.01	0.28
X11: 100 seed weight (g)	P	0.01	-0.01	0.09	0.18	0.16	0.18	0.19	-0.06	0.12	0.01	0.44	0.65
	G	0.01	-0.01	0.14	0.22	0.19	0.23	0.25	-0.08	0.15	-0.01	0.47	0.72

Note: P: phenotypic correlation; G: genotypic correlation; P residual effect= 0.5133; G residual effect= 0.2488; X12: grain yield per plant because of their highly significant genotypic and phenotypic correlations with grain yield. These characters also had the highest direct effects through most of the yield component characters. This suggests that direct selection for these traits would likely to be effective in increasing grain yield in maize.

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Association and path coefficient analysis in testcross progeny populations obtained through reciprocal recurrent selection in maize (*Zea mays* L.)

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ABSTRACT

The present investigations were carried out at AICMIP, ARS, Arabhavi to know the nature and magnitude of association among various traits and direct and indirect effects of each quantitative trait on grain yield in two testcross progenies of populations derived through reciprocal recurrent selection in maize. Phenotypic and genotypic correlation analysis revealed that, grain yield per hectare exhibited significant positive association with ear length, ear height, number of kernel rows per ear, hundred grain weight, ear girth, number of kernels per row, shelling percentage and grain yield per plot in both the populations. The path coefficient analysis at phenotypic level revealed that grain yield per plot, number of kernel rows per ear, days to 50 per cent tasseling and ear girth in population I and number of kernels per row and hundred grain weight possessed high positive direct effect on grain yield per hectare. Hence, these traits could be considered for selection for yield improvement in maize.

Keywords: Association, Correlation, Path-coefficient analysis, *Zea mays*

Maize (*Zea mays* L.) is one of the most important cereal belongs to the family Poaceae. It ranks third next to wheat and paddy in production in India. India ranks fourth in maize production (21.57 million tonnes) in the world with a productivity of 2476 kg ha^{-1} (Anon., 2013). Among the cereals grown in India, the demand for maize is increasing due to its versatile uses. Maize is used primarily as a food for humans in most areas of the world whereas in India, nearly 75% of the produce is bought by the poultry feed manufacturers and 20% is purchased by the starch extractors (Joshi *et al.,* 2005) and it even serves as an important staple food in several parts of country. Maize starch can be hydrolyzed and enzymatically treated to produce syrups (particularly high fructose corn syrup) a sweetener; and also fermented and distilled to produce grain alcohol. Ethanol is mixed with gasoline to decrease the amount of pollutants emitted when used to fuel motor vehicles. Approximately 40% of the crop is used for corn ethanol in United States of America (Thomas, 2010).

The demand for maize is increasing due to its versatile uses. The increasing demand of maize could partially be addressed either by bringing more area under maize or by increasing the productivity of the crop through the development and adoption of high yielding hybrids. Corn yield is a complex trait conditioned by the interaction of various growth and physiological processes throughout the life cycle. The appropriate knowledge of such interrelationships between grain yield and its contributing components can significantly improve the efficiency of breeding programme through the use of appropriate selection indices (Mohammadia *et al.,* 2003). The nature of association between grain yield and its components determine the appropriate traits to be used in indirect selection for improvement in grain yield. The correlation studies measures the association between yield and other traits. Whereas path analysis is a statistical technique that partitions correlations into direct and indirect effects and distinguishes between correlation and causation (Wright, 1921). Hence, the estimates of correlation and path coefficients can help us to understand the roles and relative contributions of various traits in establishing the growth behaviour of crop cultivars under given environmental conditions (Akhtar *et al*., 2007). The present investigation was undertaken to estimate correlations and path coefficients for yield and yield component traits of test cross progenies of two populations derived through reciprocal recurrent selection.

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MATERIALS AND METHODS

The initial experimental material consisted of 58 S_1 lines in Population I and 58 S_1 lines in Population II which were maintained at AICMIP, Agriculture Research Station (ARS), Arabhavi, Karnataka. The two hundred test cross progenies developed using these S_1 lines by mating in a full sib reciprocal recurrent selection fashion during *Kharif*, 2013 were evaluated in a Randomized Block Design with two replications during *Rabi/Summer* 2013-14 at ARS Arabhavi. Each entry was grown at a spacing of 75 cm x 20 cm, in a plot size of two rows of 4 m length. Border rows were raised all along the field to avoid environmental influences. All the recommended package of practices was followed to raise a good and healthy crop. The biometrical data was recorded on ten randomly selected plants for eight traits *viz.*, Plant height (cm), Ear height (cm), Ear length(cm), Ear girth(cm), Number of kernel rows per ear, Number of kernels per row, Shelling percentage and 100-seed weight. However, the data for the traits *viz.*, days to 50 per cent tasseling, days to 50 per cent silking and grain yield was recorded on plot basis. The replication wise mean values of genotypes were subjected to statistical analysis using WINDOSTAT 8.0 software. Mean values of both the population test cross progenies were subjected to correlation analysis as per the method suggested by Falconer (1967). Path coefficient analysis as proposed by Dewey and Lu (1959) was utilized for partitioning the total correlation in to direct and indirect effects.

RESULTS AND DISCUSSION

The analysis of variance (Table 1 and 2) for Population I and Population II revealed the presence of significant differences among the test cross progenies for all the traits under consideration, indicating the existence of sufficient variation in the material studied. Hence, the data was further subjected to correlation and path coefficient analysis to estimate the association existing between yield and yield contributing components and direct and indirect effects of yield related traits, respectively. Phenotypic and genotypic correlation (Table 3) analysis in Population I revealed that, grain yield per hectare exhibited significant positive association with nine traits *viz.*, days to 50% tasseling, ear length, ear height, number of kernel rows per ear, hundred grain weight, ear girth, number of kernels per row, shelling percentage and grain yield per plot.

In Population II also, grain yield per hectare possessed significant positive association with nine traits *viz.* plant height, ear height, ear length, ear girth, number of kernel rows per ear, number of kernels per row, shelling percentage, hundred grain weight and grain yield per plot. However, the most yield determinative traits were number of kernel rows per ear, number of kernels per row, ear length, ear girth and 100-seed weight among the significant and positively associated traits in both the populations. Ashofteh Biragi *et al.*, (2010) reported the positive and significant correlation of grain yield, number of kernel rows in maize. Kwaga (1994) noted significant

Table 1. Analysis of variance for twelve quantitative characters in testcross progenies of Population I

Source	Mean sum of squares		
	Replication	Treatment	Error
Degrees of freedom	1	99	99
Days to 50 % tasseling	0.59	5.86**	0.66
Days to 50% silking	1.10	5.82**	0.71
Plant height (cm)	160.53	249.08**	46.05
Ear height (cm)	28.85	98.79**	43.59
Cob length (cm)	14.40	3.70**	1.55
Cob girth (cm)	0.01	0.12**	0.04
Number of kernel rows	1.23	1.77**	1.04
Number of kernels/row	6.71	47.98**	4.97
Shelling percentage	1.95	20.94**	4.13
Hundred grain weight (g)	10.32	23.40**	10.35
Plot yield (kg/plot)	0.01	0.57**	0.18
Grain yield (q/ha)	15.17	91.67**	11.67

Note: ** Significant at 1% level of significance.

Table 2. Analysis of variance for twelve quantitative characters in testcross progenies of Population II

Characters	Mean sum of squares		
	Replication	Treatment	Error
Degrees of freedom	1	99	99
Days to 50 % tasseling	0.24	5.91**	0.73
Days to 50% silking	0.17	6.06**	0.79
Plant height (cm)	14.18	252.40**	68.67
Ear height (cm)	2.24	85.57**	41.34
Cob length (cm)	0.56	2.50**	1.45
Cob girth (cm)	0.05	0.13**	0.04
Number of kernel rows	0.12	1.43**	0.70
Number of kernels/row	5.93	47.28**	4.75
Shelling percentage	2.73	10.15**	4.29
Hundred grain weight(g)	7.11	18.50**	5.49
Plot yield (kg/plot)	0.08	0.78**	0.06
Grain yield (q/ha)	2.07	252.79**	12.25

Note: ** Significant at 1% level of significance.

Table 3. Phenotypic and genotypic correlation coefficients for grain yield and its components in maize (Population I)

Characters		Days to 50% tasseling	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernel rows per cob	No. of kernels per row	Shelling percentage	100-grain weight (g)	Grain yield (kg/plot)	Grain yield (q/ha)
Days to 50 % tasseling	rp	**1.000**	0.181 *	0.078	0.221 **	0.093	0.108	0.045	0.049	-0.130	0.073	0.174*	0.177*
	rg	**1.000**	0.096	-0.128	-0.280**	-0.124	0.107	0.049	0.049	0.127	0.064	0.137	0.158*
Days to 50 % silking	rp		**1.000**	0.093	0.237 **	0.106	0.072	0.074	0.133	-0.015	0.159*	0.042	-0.165*
	rg		**1.000**	-0.176*	-0.343**	-0.136	0.059	0.023	0.129	-0.014	0.130	0.013	-0.199**
Plant height (cm)	rp			**1.000**	0.186 **	0.230 **	0.102	0.155 *	0.055	0.095	-0.221 **	0.044	-0.179*
	rg			**1.000**	0.180**	0.240**	0.091	0.190**	0.045	0.107	0.230**	0.063	-0.267**
Ear height (cm)	rp				**1.000**	0.132	0.012	0.047	0.025	0.175 *	0.036	0.010	0.206**
	rg				**1.000**	0.283**	0.032	0.082	0.095	0.140	0.092	0.094	0.166*
Ear length (cm)	rp					**1.000**	0.235 **	0.132	0.040	0.122	0.379 **	0.034	0.210**
	rg					**1.000**	0.210**	0.145*	0.247**	0.114	0.124	0.221**	0.212**
Ear girth (cm)	rp						**1.000**	0.204 **	0.236 **	0.143*	0.011	0.056	0.193**
	rg						**1.000**	0.210**	0.145*	0.247**	0.114	0.124	0.221**
No. of kernel rows per ear	rp							**1.000**	0.205**	0.245**	0.101	0.173 *	0.201**
	rg							**1.000**	0.183**	0.328**	0.242**	0.247**	0.238**
No. of kernels per row	rp								**1.000**	0.220**	0.163 *	0.087	0.190**
	rg								**1.000**	0.214**	0.246**	0.075	0.204**
Shelling percentage (%)	rp									**1.000**	0.146	0.094	0.187*
	rg									**1.000**	0.158*	0.184*	0.192**
Hundred grain weight (g)	rp										**1.000**	0.175*	0.198**
	rg										**1.000**	0.135	0.171*
Grain yield (kg/plot)	rp											**1.000**	0.152*
	rg											**1.000**	0.186**
Grain yield (q/ha)	rp												**1.000**
	rg												**1.000**

Note: *-Significant at 5% level, **-Significant at 1% level of significance

Table 4. Phenotypic and genotypic correlation coefficient for grain yield and its components in maize (Population II)

Characters		Days to 50% tasseling	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernel rows per cob	No. of kernels per row	Shelling percentage	100-grain weight (g)	Grain yield (kg/plot)	Grain yield (q/ha)
Days to 50 % tasseling	**rp**	**1.000**	0.104	0.105	0.076	0.091	-0.073	0.018	-0.205**	-0.195 **	0.028	0.109	-0.193**
	rg	**1.000**	0.198**	0.020	0.258**	0.189**	0.054	0.041	-0.083	-0.267**	-0.077	0.016	-0.168*
Days to 50 % silking	**rp**		**1.000**	0.058	0.176 *	0.063	0.104	0.031	-0.152*	-0.197 **	0.135	-0.062	-0.183**
	rg		**1.000**	0.112	0.260**	0.142*	0.010	0.009	-0.084	-0.260**	0.071	-0.037	-0.157*
Plant height (cm)	**rp**			**1.000**	0.075	0.173*	0.013	-0.097	0.165*	-0.062	-0.025	0.131	0.182**
	rg			**1.000**	0.186**	0.082	0.012	0.065	0.161*	-0.036	0.240**	0.225**	0.189**
Ear height (cm)	**rp**				**1.000**	0.095	0.170*	0.159 *	-0.057	-0.141	0.130	0.165*	0.209**
	rg				**1.000**	0.204**	0.238**	0.066	-0.089	-0.268**	0.182**	0.051	0.166*
Ear length (cm)	**rp**					**1.000**	0.176 *	0.054	0.032	0.167 *	0.412 **	0.105	0.293**
	rg					**1.000**	0.119	0.069	0.103	0.137*	0.607**	0.183**	0.232**
Ear girth (cm)	**rp**						**1.000**	0.174 *	0.204**	0.030	0.067	0.216**	0.225**
	rg						**1.000**	0.239**	0.100	0.166*	0.139*	0.024	0.215**
No. of kernel rows per ear	**rp**							**1.000**	0.023	0.270**	0.103	0.101	0.396**
	rg							**1.000**	0.030	0.297*	0.164*	0.024	0.192**
No. of kernels per row	**rp**								**1.000**	0.188 *	0.637**	0.271**	0.342**
	rg								**1.000**	0.286*	0.250**	0.105	0.277**
Shelling percentage (%)	**rp**									**1.000**	0.113	0.242**	0.260**
	rg									**1.000**	0.155*	0.201**	0.153*
Hundred grain weight (g)	**rp**										**1.000**	0.208**	0.195**
	rg										**1.000**	0.122	0.187*
Grain yield (kg/plot)	**rp**											**1.000**	0.178*
	rg											**1.000**	0.167*
Grain yield (q/ha)	**rp**												**1.000**
	rg												**1.000**

Note: *-Significant at 5% level, **-Significant at 1% level of significance

Table 5. Direct and indirect effects of different characters on grain yield (Phenotypic level, Population I and Population II)

Characters	Population	Days To 50% tasseling	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernel rows ear^{-1}	No. of kernels per row	Shelling (%)	100 grain weight (g)	Grain yield per plot (kg)	'r' with grain yield ha^{-1}
Days to 50 % tasseling	Population I	**0.242**	0.064	0.219	-0.237	0.111	0.087	-0.311	0.102	-0.213	0.068	0.048	0.177*
	Population II	**-0.193**	0.143	-0.136	0.076	-0.025	-0.054	0.096	0.107	-0.160	-0.058	0.013	-0.193**
Days to 50 % silking	Population I	0.106	**-0.107**	0.039	0.049	-0.203	-0.102	0.016	0.147	-0.175	-0.032	0.109	-0.165*
	Population II	0.069	**0.139**	0.057	-0.329	0.071	0.124	0.035	-0.179	0.134	-0.243	-0.061	-0.183**
Plant height (cm)	Population I	-0.219	0.013	**0.133**	0.065	0.071	0.010	0.025	-0.158	-0.313	0.129	0.066	-0.179**
	Population II	-0.103	0.041	**-0.131**	0.136	0.102	0.184	-0.063	0.132	-0.152	-0.136	0.174	0.182**
Ear height (cm)	Population I	0.131	-0.207	0.218	**-0.130**	-0.025	0.062	0.097	0.217	-0.150	0.125	-0.131	0.206**
	Population II	-0.267	-0.186	0.106	**0.192**	0.139	0.019	-0.029	0.075	0.194	0.019	-0.052	0.209**
Ear length (cm)	Population I	0.206	-0.176	-0.096	0.124	**0.132**	0.031	0.104	-0.225	-0.116	0.103	0.125	0.210**
	Population II	0.181	-0.101	0.161	-0.343	**0.180**	0.227	0.073	0.175	0.033	-0.252	-0.041	0.293**
Ear girth (cm)	Population I	-0.132	-0.301	0.141	0.083	-0.154	**0.218**	0.094	0.134	0.132	0.194	-0.216	0.193**
	Population II	-0.162	0.058	-0.32	0.013	-0.186	**0.181**	0.136	0.209	0.176	0.214	-0.093	0.225**
No. of kernel rows per ear	Population I	-0.141	0.102	-0.584	0.161	0.164	0.207	**0.245**	0.138	-0.381	0.127	0.164	0.201**
	Population II	0.162	-0.094	0.143	-0.324	0.148	-0.205	**0.138**	0.037	0.150	0.094	0.146	0.394**
No. of kernels per row	Population I	0.106	0.084	-0.396	0.133	0.095	0.121	0.162	**0.192**	0.164	-0.299	-0.170	0.190**
	Population II	-0.204	-0.181	0.131	-0.144	0.082	0.142	0.074	**0.232**	0.173	-0.193	0.232	0.343**
Shelling percentage	Population I	0.062	-0.216	0.115	-0.386	0.082	0.130	0.105	0.073	**0.138**	-0.093	0.137	0.187**
	Population II	-0.22	-0.251	0.107	0.070	0.169	0.147	0.108	-0.122	**0.186**	0.141	-0.074	0.260**
Hundred grain weight (g)	Population I	-0.147	0.153	0.097	-0.035	0.174	-0.132	-0.103	0.186	0.126	**-0.202**	0.082	0.198**
	Population II	0.073	0.053	-0.162	-0.172	0.104	0.172	-0.102	0.113	0.062	**0.216**	-0.161	0.195**
Grain yield per plot (kg)	Population I	0.264	-0.176	0.132	-0.169	0.162	0.102	0.076	0.075	0.133	-0.214	**0.252**	0.152*
	Population II	0.131	-0.281	0.126	-0.182	0.163	0.184	-0.143	0.104	0.136	0.091	**0.151**	0.178*

Note: *-Significant at 5% level, **-Significant at 1% level;
Residual effect = 0.323, 0.265 (Population I, Population II),
Diagonals = Direct effect (bold); off diagonals = Indirect effects

positive relationship of grain yield with ear length, ear circumference and 100 grain weight. Similarly positive correlation between grain yield and 100 grain weight in maize was reported by Inamullah *et al.* (2011). Earlier workers (Devi *et al.*, 2001, El-Shouny *et al.*, 2005, Mohan *et al.*, 2002, Tollenaar *et al.*, 2004) identified that the traits like ear length, ear diameter, kernels per row, kernel rows per ear and 100-seed weight as potential selection criteria in breeding programmes aiming at higher yield. Thus simultaneous selection for these traits or else a combination among these traits may bring an improvement in maize grain yield.

On contrary, grain yield per hectare exhibited significant negative association with days to 50 % tasseling and days to 50 % silking in population I and days to 50 % silking in both populations, indicated that early silking is desirable for increasing grain yield. Similar results were reported by Kwaga (1994).

The association studies are helpful in determining the components of yield. However, with the inclusion of more variables, the indirect association becomes more complex. Two traits may show correlation because they may correlate with a common third one. Under such circumstances path analysis helps in further partitioning of correlation coefficient into direct and indirect effects, permitting a critical examination of the relative importance of each traits. The direct and indirect effects of the traits are presented and discussed as per the classification by Lenka and Mishra (1973).

The results of path coefficient analysis at phenotypic level grain yield per plot (0.252) has maximum positive direct effect on grain yield per hactare followed by number of kernel rows per ear (0.245), days to 50 per cent tasseling (0.242), ear girth (0.218), number of kernels per row (0.192), shelling percentage (0.138), plant height (0.133) and ear length (0.132) in population I (Table 5). On contrary, the one important trait hundred grain weight exerted negative direct effects on yield per hectare. However, the negative indirect effects of hundred grain weight was nullified by the indirect positive effects of number of kernels per row, ear length, days to silking and shelling percentage which ultimately resulted in to highly significant positive correlation of hundred grain weight with grain yield per hectare. These results are in agreement with the results of Yousuf & Saleem 2001 and Sadek *et al.*, 2006. Thus, these traits could be exploited for selection of genotypes to improve genetic yield potential of maize.

In the population II, the trait number of kernels per row (0.232) influenced grain yield per hectare directly and predominantly followed by hundred grain weight (0.216), ear height (0.192), shelling percentage (0.186), ear girth (0.181), ear length (0.180), grain yield per plot (0.151), number of kernel rows per ear (0.138) and days to 50 per cent silking (0.139). Similar results were also reported for cob length (Wannows *et al.*, 2010); for cob girth (Sofi *et al.*, 2007); for number of kernels per row (Mohan *et al.*, 2002) and for 100-seed weight (Venugopal *et al.*, 2003). Further, the association of these traits with grain yield per hectare was also positive and highly significant, indicating the importance of these traits for grain yield improvement in the present material. Besides this, the traits hundred grain weight, ear length, ear girth and number of kernels per row also influenced grain yield per hectare indirectly in a substantial magnitude through most of the other yield components as evident in the results (Table 5). Thus, selection for the genotypes with maximum ear length and ear girth accommodating more number of kernels per row and giving more 100 seed weight is a pre-requisite for attaining improvement in grain yield per hectare using the present material.

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Exploitation of heterosis for seed yield through diallel crosses of maize (*Zea mays* L.)

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ABSTRACT

The study conducted to assess magnitude of heterosis of 28 single cross hybrids developed by half-diallel mating design without reciprocal crosses involving 8 parents and evaluated against 2 standard checks *viz.* GAYMH-1 and HQPM-1 in randomized block design with three replications at Agronomy Farm, AAU, Anand in *rabi* 2014-15. The results revealed significant differences between parents and hybrids for grain yield and yield attributing characters. The hybrid, HKI-163 x CM-500-1 exhibited significant and desirable heterosis for grain yield per plant, days to 50% tasselling, days to 50% silking, plant height, ear height and ear length; whereas a cross, CML-307 x HKI-163 observed significant and positive for relative heterosis and heterobeltiosis for grain yield per plant, plant height and number of grains per row. In addition, the hybrid, CML-307 x HKI-193-1 showed significant and positive relative heterosis and heterobeltiosis for grain yield per plant, plant height, ear height, ear length, number of kernel rows per ear and number of grains per row. Hence, it may be concluded that these hybrids could be exploited to improve grain yield potential through heterosis for development of superior genotypes.

Keywords: Grain yield, Half diallel, Heterosis, Hybrid

Maize (*Zea mays* L.) is the third most important cereal crop next to rice and wheat. It has highest production potential among cereals. There is no other cereal on the earth, which has such immense potential of diversified uses and productivity as maize. Heterosis is pre-requisite to develop good economically productive hybrids. The information on the heterotic patterns of maize is essential in maximizing effectiveness of hybrid development programme. Therefore, the studies were conducted to identify best cross combinations and may be exploited through heterosis breeding programme for improvement of grain yield and its attributing traits.

MATERIALS AND METHODS

The field experiment conducted at the Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) during *rabi* 2014-15. The experimental material consisted of 8 parental inbred lines like 'CML-307', 'CM-111', 'CLQ-7', CM-140, CM-137, HKI-163, HKI-193-1 and CM-500-1 and their 28 single cross hybrids developed by diallel mating scheme without reciprocals (Griffing method-II; Griffing, 1956b) and 2 standard checks, GAYMH-1 and HQPM-1. The seeds of parental inbreds and 28 hybrids were produced during *rabi* 2013-14 hand pollination.

The crosses, parental inbred lines and checks were sown in Randomized Complete Block Design with 3 replications consisted of two rows of each treatment of 4 m length with spacing of 60 cm x 20 cm. The cultivation practices followed as per recommendations to raise normal crop for optimum yield potential expression. The observations were recorded from five randomly selected plants per treatment in each replication for the eleven characters *viz.* days to 50% tasselling, days to 50% silking, days to 75% brown husk, plant height (cm), ear height (cm), ear length (cm), ear girth (cm), number of kernel rows per ear, number of kernels per row, 100-kernel weight (g) and Grain yield per plant (g) as per standard methods laid by Indian Institute of Maize Research, ICAR, New Delhi.

The analysis of variance (Panse and Sukhatme, 1967) was used to test the differences among genotypes. Heterotic effects were estimated in terms of three parameters relative heterosis (RH) suggested by Turner (1953), heterobeltiosis (HB) suggested by Fonseca and Patterson (1968) and standard heterosis (SH) suggested by Meredith and Bridge (1972).

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Table 1. Analysis of variance for various characters in Maize

Source of variance	d.f.	Mean squares										
		Days to 50% tasselling	Days to 50% silking	Days to 75% brown husk	Plant height	Ear height	Ear length	Ear girth	No.of grain rows per ear	No. of grains per row	100-kernel weight	Grain yield per plant
Replications	2	6.37	3.00	5.17	82.11	4.30	0.12	0.13	0.014	0.39	1.27	92.72
Genotypes	37	3.58*	3.65*	14.12*	391.12**	235.64**	5.12**	0.59**	1.24**	15.10**	9.95**	602.94**
Parents	7	7.04**	9.11*	25.12*	101.31	170.05**	6.50**	0.70**	1.83**	13.12	13.85**	946.01**
Hybrids	27	2.37	2.15	11.45	220.03**	221.11**	4.01**	0.57**	1.13**	14.45**	8.22**	490.63**
Between Checks	1	2.66	4.16	6.00**	0.427	22.815	2.54**	0.028	0.807**	1.927	7.41**	13.82
Parents *vs* Hybrids	1	11.87*	5.84	8.75	7043.17**	1087.64**	19.58**	0.18	0.088	46.52*	29.12**	1233.05**
Checks *vs* Hybrids	1	14.89*	15.11*	0.020	89.97	121.76	0.009	2.23**	3.86**	30.24	8.17	788.73*
Error	74	2.03	2.00	8.85	53.56	54.79	0.42	0.15	0.18	7.00	1.73	37.96

*, **significant 5% and 1% levels, respectively.

Table 2. Mean performance of parents hybrids for various characters in Maize

Individuals	Days to 50% tasselling	Days to 50% silking	Days to 75% brown husk	Ear height	Plant height	Ear length	Ear girth	No. of grain rows per ear	No. of grains per row	100-kernel weight	Grain yield per plant
Parental mean	59.16	63.83	79.63	175.4	105.16	14.0	11.90	12.90	26.70	19.40	143.40
Hybrids mean	59.00	63.16	88.58	194.8	107.33	15.2	12.00	12.90	28.20	20.60	151.50
General mean	59.62	63.72	91.82	190.91	103.42	14.96	12.00	12.97	28.03	20.45	150.40

Table 3. Estimates of relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) of top three crosses for yield and its attributes in Maize

Cross	RH (%)	Cross	HB (%)	Cross	SH 1 (%)	Cross	SH 2 (%)
Days to 50% tasselling							
HKI – 163 x CM – 500 – 1	-5.41**	CML – 307 x CM – 111	-7.03**	CML – 307 x CM – 111	-7.03**	CML – 307 x CM – 111	-4.97**
CML – 307 x CM – 111	-4.44**	HKI – 163 x CM – 500 – 1	-5.41**	HKI – 163 x CM – 500 – 1	-5.41**	HKI – 163 x CM – 500 – 1	-3.31**
CM – 111 x HKI – 163	-3.24**	CM – 140 x HKI – 193 – 1	-4.86**	CM – 137 x HKI – 163	-5.41**	CM – 137 x HKI – 163	-3.31**
(HKI – 163 x HKI – 193 – 1)	2.54**	(HKI – 163 x HKI – 193 – 1)	1.11	(CML – 307 x HKI – 163)	-1.08	(CML – 307 x HKI – 163)	1.10
Days to 50% silking							
HKI – 163 x CM – 500 – 1	-5.32**	HKI – 163 x CM – 500 – 1	-6.03**	CML – 307 x CM – 111	-6.57**	CML – 307 x CM – 111	-4.15*
CLQ – 47 x CM – 500 – 1	-3.59*	CM – 137 x HKI – 193 – 1	-5.03**	HKI – 163 x CM – 500 – 1	-5.56**	HKI – 163 x CM – 500 – 1	-3.11
CML – 307 x CM – 111	-3.14*	CML – 307 x CM – 111	-4.64**	CM – 137 x HKI – 163	-5.56**	CM – 137 x HKI – 163	-3.11
(CLQ – 47 x CM – 140)	1.85	(CM – 140 x CM – 137)	0.53	(CM – 140 x HKI – 163)	-2.02	(HKI – 163 x HKI – 193 – 1)	0.52
Days to 75% brown husk							
CLQ – 47 x CM – 500 – 1	-4.43**	CLQ – 47 x CM – 500 – 1	-6.50**	CLQ – 47 x CM – 500 – 1	-1.63**	CLQ – 47 x CM – 500 – 1	-3.51**
CLQ – 47 x CM – 140	-3.03**	CLQ – 47 x CM – 137	-6.19**	HKI – 163 x HKI – 193 – 1	-1.63**	HKI – 163 x HKI – 193 – 1	-3.51**
CLQ – 47 x CM – 137	-2.88**	CLQ – 47 x CM – 140	-5.88**	CLQ – 47 x CM – 137	-1.30**	CLQ – 47 x CM – 137	-3.19**
(CM – 137 x HKI – 163)	3.32**	(CM – 137 x HKI – 163)	3.32**	(CM – 111 x CLQ – 47)	4.89**	(CM – 111 x CLQ – 47)	2.88**
Plant height							
CML – 307 x CM – 500 – 1	19.25**	HKI – 193 – 1 x CM – 500 – 1	15.82**	HKI – 193 – 1 x CM – 500 – 1	5.94**	HKI – 193 – 1 x CM – 500 – 1	5.66**
CM – 140 x CM – 137	17.08**	CML – 307 x CM – 500 – 1	14.90**	CM – 137 x HKI – 163	4.50**	CM – 137 x HKI – 163	4.22**
HKI – 193 – 1 x CM – 500 – 1	16.83**	CLQ – 47 x HKI – 193 – 1	14.67**	HKI – 163 x CM – 500 – 1	3.46**	HKI – 163 x CM – 500 – 1	3.18**
(CML – 307 x CM – 111)	2.47**	(CML – 307 x CM – 111)	-0.30	(CML – 307 x CM – 111)	-12.16**	(CML – 307 x CM – 111)	-12.39**
Ear height							
CML – 307 x HKI – 193 – 1	36.98**	CML – 307 x HKI – 193 – 1	26.91**	CML – 307 x CM – 137	11.29**	CML – 307 x CM – 137	15.82**
CML – 307 x CM – 137	33.20**	CML – 307 x CLQ – 47	26.43**	CML – 307 x HKI – 193 – 1	11.22**	CML – 307 x HKI – 193 – 1	15.75**
CML – 307 x CLQ – 47	31.01**	CML – 307 x CM – 137	20.51**	CML – 307 x CLQ – 47	1.60**	CML – 307 x CLQ – 47	5.74**
(CM – 140 x HKI – 163)	-13.82**	(CML – 307 x CLQ – 47)	-15.68**	(CML – 307 x CM – 140)	-20.24**	(CML – 307 x CM – 140)	-17.00**
Ear length							
HKI – 163 x CM – 500 – 1	24.22**	CM – 140 x CM – 500 – 1	16.82**	CM – 140 x CM – 500 – 1	9.17**	CM – 140 x CM – 500 – 1	18.97**
CML – 307 x HKI – 193 – 1	24.04**	HKI – 163 x CM – 500 – 1	14.71**	CM – 137 x HKI – 193 – 1	8.70**	CM – 137 x HKI – 193 – 1	18.47**
CM – 140 x CM – 500 – 1	23.13**	CML – 307 x CM – 111	13.43**	CLQ – 47 x CM – 140	4.32	CLQ – 47 x CM – 140	13.69**
(CML – 307 x CM – 137)	-13.11**	(CM – 137 x CM – 500 – 1)	-21.08**	(CM – 137 x CM – 500 – 1)	-16.50**	(CM – 137 x CM – 500 – 1)	-9.00**

Table 3 *cont....*

Cross	RH (%)	Cross	HB (%)	Cross	SH 1 (%)	Cross	SH 2 (%)
Ear girth							
CM – 111 x HKI – 193 – 1	9.26**	CM – 140 x CM – 500 – 1	6.24**	CLQ – 47 x HKI – 193 – 1	0.72	CLQ – 47 x HKI – 193 – 1	-0.37
CM – 111 x CLQ – 47	8.24**	CM – 111 x HKI – 193 – 1	5.15**	CM – 111 x CLQ – 47	-0.29	HKI – 163 x HKI – 193 – 1	-1.37
CM – 140 x CM – 500 – 1	6.56**	CLQ – 47 x HKI – 193 – 1	3.35**	HKI – 163 x HKI – 193 – 1	-0.29	CM – 111 x CLQ – 47	-1.37
(CLQ – 47 x CM – 137)	-8.96**	(CLQ – 47 x CM – 137)	-9.01**	(CLQ – 47 x CM – 137)	-11.23**	(CLQ – 47 x CM – 137)	-12.19**
Number of kernel rows per ear							
CM – 111 x CM – 140	14.67**	CM – 111 x CM – 140	10.26**	CM – 111 x CM – 140	6.97**	CM – 111 x CM – 140	1.42
CML – 307 x CM – 111	12.18**	CML – 307 x CM – 111	10.00**	CLQ – 47 x HKI – 163	6.97**	CLQ – 47 x HKI – 163	1.42
CML – 307 x HKI – 193 – 1	8.30**	CLQ – 47 x HKI – 163	6.44**	HKI – 163 x HKI – 193 – 1	4.98**	HKI – 163 x HKI – 193 – 1	-0.47
(CM – 140 x CM – 137)	-7.69**	(CM – 111 x CM – 137)	-12.26**	(CML – 307 x HKI – 163)	-10.2**	(CML – 307 x HKI – 163)	-4.86**
Number of grains per row							
CLQ – 47 x CM – 500 – 1	20.72**	CML – 307 x CM – 111	15.68**	CM – 137 x HKI – 193 – 1	4.00**	CM – 137 x HKI – 193 – 1	0.21
CML – 307 x CM – 111	20.16**	CM – 111 x HKI – 193 – 1	14.93**	HKI – 163 x HKI – 193 – 1	3.78**	HKI – 163 x HKI – 193 – 1	0.08
CML – 307 x CM – 500 – 1	19.87**	CM – 111 x CM – 500 – 1	13.66**	CM – 140 x HKI – 163	2.67	CM – 140 x HKI – 163	-1.07
(CM – 140 x CM – 137)	-10.32**	(CM – 140 x CM – 500 – 1)	-19.51**	(CM – 140 x CM – 500 – 1)	-19.78**	(CM – 140 x CM – 500 – 1)	-22.70**
100-kernel weight							
CML – 307 x CM – 140	34.47**	CML – 307 x CM – 140	19.00**	CM – 111 x CM – 140	2.71	CM – 111 x CM – 140	13.72**
CM – 111 x CM – 140	33.47**	CM – 111 x CM – 140	12.66**	CM – 140 x CM – 500 – 1	-1.41	CM – 140 x CM – 500 – 1	9.16**
CM – 140 x CM – 500 – 1	29.85**	CML – 307 x CLQ – 47	12.38**	CM – 111 x HKI – 163	-1.73	CM – 111 x HKI – 163	8.81**
(CM – 111 x CLQ – 47)	-17.13**	(CM – 111 x CLQ – 47)	-19.93**	(CM – 111 x CLQ – 47)	-27.00**	(CM – 111 x CLQ – 47)	-19.17**
Grain yield per plant							
HKI – 163 x CM – 500 – 1	35.95**	HKI – 163 x CM – 500 – 1	35.17**	CML – 307 x HKI – 163	5.89**	CML – 307 x HKI – 163	3.94**
CML – 307 x HKI – 163	34.56**	CML – 307 x HKI – 163	29.04**	CLQ – 47 x CM – 500 – 1	4.96**	CLQ – 47 x CM – 500 – 1	3.03**
CML – 307 x HKI – 193 – 1	30.62**	CML – 307 x HKI – 193 – 1	24.57**	CLQ – 47 x HKI – 163	4.59**	CLQ – 47 x HKI – 163	2.67**
(CLQ – 47 x CM – 137)	-16.49**	(CML – 307 x CM – 137)	-19.00**	(CML – 307 x CM – 111)	-19.77**	(CML – 307 x CM – 111)	-21.25**

In each character, the parenthesis ( ) indicate the cross which showed lowest heterosis.
Standard Check 1 = GAYMH – 1, Standard Check 2 = HQPM – 1.
*, ** significant at 5% and 1% levels, respectively.

RESULTS AND DISCUSSION

The analysis of variance for genotypes, parents and hybrids found highly significant for most of the characters indicating existence of considerable amount of genetic variability for the traits under study (Table 1). The parents showed significant differences for all the characters except plant height and number of grains per row which revealed existence of sufficient variability among all parents. The parents' vs hybrids also exhibited significant variability for days to 50% tasselling, plant height, ear height, ear length, number of grains per row, 100-kernel weight and grain yield per plant that suggested presence of heterosis. The mean performance of hybrids were found extremely promising than parents for grain yield per plant and most of other characters except days to 75% brown husk, which revealed that hybrids largely exceeded for the expression of the characters and possibility for higher heterotic effects (Table 2).

Relative heterosis, heterobeltiosis and standard heterosis 1 and standard heterosis 2 ranged from -16.49 to 35.95, -19.00 to 35.17, -19.77 to 5.89 and -21.25 to 3.94 per cent for grain yield per plant, respectively (Table 3). The cross, CML-307 x HKI-163 showed positive and significant result for relative heterosis, heterobeltiosis and standard heterosis over both the checks; whereas the crosses HKI-163 x CM-500-1 and CML-307 x HKI-193-1 gave the positive and significant relative heterosis, heterobeltiosis and standard heterosis over check GAYMH-1 for grain yield per plant. The cross HKI-163 x CM-500-1 also showed significant and desirable relative heterosis, heterobeltiosis and standard heterosis for the characters days to 50% tasselling, days to 50% silking, plant height, ear height and ear length; whereas the hybrid CML-307 x HKI-163 revealed significant and positive relative heterosis and heterobeltiosis for plant height and number of grains per row but standard heterosis for days to 75% brown husk; while the cross CML-307 x HKI-193-1 showed significant and positive relative heterosis and heterobeltiosis for plant height, ear height, ear length, number of kernel rows per ear and number of grains per row.

Based on over all study, the parental lines CML-307 and HKI-163 yielded better heterotic hybrids for grain yield and other yield attributes. Hence, these parents could be exploited to improve grain yield potential and used in future breeding programme for development of superior genotypes

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Gene action and heterosis for yield and yield traits in maize (*Zea mays* L.)

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ABSTRACT

A line × tester analysis was conducted in maize involving seven lines and five testers for grain yield and its components to determine the standard heterosis as well as general combining ability (*gca*) and specific combining ability (*sca*) effects during rainy season, 2012 at Agricultural Research Station, Karimnagar. Analysis of variance showed highly significant genotypic differences for all the traits indicating wide range of variability among the genotypes. Results of the combining ability analysis revealed that non additive gene actions were important for ear length, number of kernels per row and grain yield per plant and additive gene actions were responsible for the remaining traits. There was a great contribution of lines towards *gca* variance for all the traits except ear height and grain yield per plant. Among the lines, PFSR-3 was the best combiner for grain yield per plant, plant height and 100 kernel weight. Line KML-369 was excellent combiner for the ear characters *viz.*, ear girth, number of kernel rows per ear, number of kernels per row and grain yield per plant. Among the testers, KML-461 was the best combiner for plant height, ear height, ear girth, number of kernel rows per ear and grain yield per plant. KML-369 × KML-802 hybrid having desirable specific combining ability effects for ear girth, number of kernel rows per ear, grain yield per plant and 100 kernel weight. This hybrid also recorded significant positive standard heterosis for ear girth, number of kernel rows per ear, significant negative heterosis for days to 50% pollen shed, days to 50% silk emergence and positive heterosis for grain yield per plant and has potential for genetic exploitation in terms of earliness coupled with yield.

Keywords: Combining ability, Grain yield, Line × tester analysis, Maize, Standard heterosis.

Maize is the third most important cereal crop after wheat and rice both in India and world. Maize is a highly cross pollinated C_4 plant species, can be cultivated as rainfed crop in the *kharif* and irrigated crop in *rabi* season. In India during 2013-14, maize was cultivated in an area of 9.07 mha with a production of 24.3 million MT and average productivity of 2680 kg/ha (CMIE, 2014). Telangana is an important state where the maize crop is grown round the year. It is cultivated in an area of about 6.29 lakh hectares of which 4.66 lakh hectares is grown in *kharif* season and remaining 1.63 lakh hectares during *rabi*. The area under maize is increasing both in *kharif* and *rabi* due to crop shift towards irrigated dry crops like maize, soybean, cotton, sun flower, sesamum *etc*. instead of rice. Hence, it is felt necessary to breed hybrids with high grain yield and yield contributing characters suitable to rainy season (*kharif*). *Kharif* maize yields are generally lower than *rabi* due to high incidence of pests and diseases and low photoperiod. Present study was carried out with the objective of finding out the extent of heterosis and gene action exhibited in cross combinations, for ten economically important characters in *Kharif* maize.

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MATERIALS AND METHODS

Seven maize lines *viz*., PFSR-2, PFSR-3, PFSR-6, PFSR-7, KML-4, KML-79 and KML-369 were crossed with five testers *viz*., KML-80, KML-370, KML-461, KML-801 and KML-802 in a line × tester mating design at Agricultural Research Station, Karimnagar during *rabi* 2011-12 to generate a total of 35 hybrids. Post Flowering Stalk Rot resistant (PFSR) lines were obtained from Indian Institute of Maize Research (IIMR), New Delhi and remaining lines and testers were developed by pedigree breeding. During rainy (*kharif*) season, 2012 the resultant 35 crosses were evaluated in a randomized block design with three replications with row-to-row and plant-to-plant spacing of 75 cm × 20 cm, respectively. The data was recorded on five randomly selected plants for plant height (cm), ear height (cm), ear length (cm), ear girth (mm), number of kernel rows ear^{-1}, number of kernels row^{-1}, 100 kernel weight (g) and grain yield plant^{-1} (g), whereas for days to 50% pollen shed and days to 50% silk emergence data was recorded on plot basis. The data was then subjected to Randomized Block Design and found that there were significant differences among genotypes. Further, combining ability was done as suggested by Kempthorne (1957). Mean values were used for the estimation of standard heterosis using the high yielding private hybrid check 30v92 of Pioneer Overseas Pvt Ltd. and is highly susceptible to late-wilt in wilt prone areas of Northern Telangana. Heritability in narrow sense [h^2 (ns)] was computed from the variance components using the formula $\neg^2A/ \neg^2A+\neg^2D+\neg^2E$.

RESULTS AND DISCUSSION

The analysis of variance for combining ability revealed that the mean sum of squares due to lines, testers and line × tester was significant for all characters except lines for grain yield plant^{-1}, testers for plant height, number of kernels row^{-1} and 100 kernel weight, both lines and testers for ear length indicating substantial degree of variation for majority of the characters (Table 1). The non significant variance for either lines or testers for characters suggest that the lines or testers chosen had comparable potential for the corresponding traits. A higher proportion of $\neg^2$gca over $\neg^2$sca for plant height, ear height, number of kernel rows ear^{-1} and 100 kernel weight indicated the importance of additive gene action in the inheritance of these traits whereas, for other traits inheritance was under the control of non additive gene action indicated by preponderance of non additive genetic variance. Similar findings were reported by Surya and Ganguly (2004).

Estimates of general combining ability effects revealed that lines PFSR-3, KML-369 and tester KML-461 were good general combiners for grain yield per plant coupled with one or more yield contributing characters (Table 2). Estimates of specific combining ability effects indicated that the cross combinations PFSR-2 × KML-461, PFSR-3 × KML-370, PFSR-6 × KML-80, PFSR-7 × KML-80, PFSR-7 × KML-461, and KML-369 × KML-802 were good specific combiners for grain yield per plant (Table 3). Studies indicated that the superior crosses were between high × low and high × high combining parents, suggesting that the involvement of one good general combiner appear to be essential to get the best specific combination. Highest yielder KML-369 × KML-802 also ranked first and was the outcome of high × low combining parents. Surya and Ganguly (2004) and Iqbal *et al*. (2007) reported high positive specific combining ability effects with high *per se* performance for grain yield. The superiority of crosses involving high × low combiner as parents could be explained based on the interaction between positive alleles from good combiners and negative alleles for the poor combiners as parents. The high yield of such crosses would be non-fixable and thus could be exploited for heterosis breeding.

The magnitude of mean sum of squares due to Parents Vs Crosses, which can be taken as a measure of heterosis, were highly significant for all the characters which indicated that the parents chosen were diverse and with a different genetic background. These results were in confirmation with Rajesh *et al*. (2015), Avinashe *et al*. (2013) and Premalatha *et al*. (2011). The values of heterosis expressed as percent increase over the standard check 30v92. The heterosis over standard check is referred as standard heterosis or economic heterosis. The magnitude and direction of heterosis deferred in different cross combinations. None of the crosses showed significant and positive standard heterosis over the ruling high yielding private sector hybrid check 30v92 for grain yield plant^{-1}, plant height and number of kernels row^{-1}. For ear height the mean values in crosses ranged from 64 cm to 136 cm. Eight cross combinations recorded positive and significant standard heterosis ranging from 14.79 to 43.31%, for ear length five crosses recorded positive and significant standard heterosis ranging from 2.80 to 6.17%. Six and eight cross combinations recorded significant and positive standard heterosis for ear girth (2.15 to 11.57%) and kernel rows ear^{-1} (2.13 to 8.51%), respectively. About twenty crosses showed significant and positive heterotic effects over check for 100 kernel weight (2.66 to 18.59%). The crosses KML-79 × KML-461, KML-369 × KML-461 and KML-369 × KML-802 had significant and positive standard heterotic effects for both ear girth and number of kernel rows ear^{-1} indicating greater ear girth resulted in more number of kernel rows ear^{-1}. Tester KML-80 with lines PFSR-6, PFSR-7 and KML-4 recorded significant and positive standard heterotic effects for ear length. All the PFSR lines, i.e. PFSR-2, PFSR-3, PFSR-6 and PFSR-7 with testers KML-80, KML-370, KML-461 and KML-801 recorded significant and positive standard heterotic effects for 100 kernel weight, clearly evident that these inbreds could be utilized in development of bold kernel hybrids with good test weight. These results were in confirmation with Bhavana *et al*. (2011) and Singh *et al*. (2010).

Table 1. Analysis of variance (mean squares) for combining ability for different traits in line × tester cross of maize (*Zea mays* L.)

Source of variation	d.f.	Days to 50% pollen shed	Days to 50% silk emergence	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (mm)	No.of kernel rows ear^{-1}	No. of kernels row^{-1}	100 kernel weight (g)	Grain yield plant^{-1} (g)
Replications	2	0.830	0.220	77.582	2.922	3.278	1.213*	0.007	3.411	1.837	173.410
Genotypes	46	2032.053*	2160.867**	25215.060**	5579.166**	241.616**	141.229**	119.387**	760.747**	845.393**	19644.510**
Parents	11	961.000**	1034.694**	12432.250**	2240.444**	120.268**	66.422**	61.361**	427.111**	354.695**	11060.030**
Parents vs crosses	1	82718.680**	87774.020**	984424.500**	20907.400**	9607.015**	5697.926**	4630.201**	29639.900**	33747.670**	740735.800**
Crosses	34	5.434**	7.183**	1138.629**	655.569**	5.423**	1.999**	5.489**	19.301**	36.434**	1213.281**
Lines	6	11.416**	17.194**	4812.165**	1219.378**	7.704	3.954*	20.616**	47.197*	155.238**	1236.327
Testers	4	13.810**	14.462*	619.062	2718.262**	8.775	4.475*	5.300*	7.324	18.548	3226.510*
Line × testers	24	2.543**	3.467**	306.840**	170.834**	4.295**	1.097**	1.739*	14.324**	9.714**	871.982**
Error	92	0.467	0.539	79.596	40.335	1.222	0.296	0.717	4.324	1.685	57.324
¬^{2}L		0.592**	0.915**	300.355**	69.903**	0.227	0.19	1.259**	2.192*	9.702**	24.29
¬^{2}T		0.537**	0.524*	14.868	121.306**	0.213	0.161	0.17	-0.333	0.421	112.120*
¬^{2}gca		0.559**	0.687**	133.82**	99.888**	0.219	0.173	0.623*	0.719	4.288**	75.524*
¬^{2}sca		0.672**	0.940**	67.239**	38.977**	0.896**	0.237**	0.260*	2.836**	2.518**	266.441**
¬^{2}gca/¬^{2}sca		0.833	0.731	1.990	2.563	0.245	0.731	2.402	0.253	1.703	0.283
¬^{2}A		1.119	1.373	267.642	199.776	0.438	0.346	1.247	1.437	8.575	151.049
¬^{2}D		0.672	0.940	67.239	38.977	0.896	0.237	0.260	2.836	2.518	266.441
¬^{2}A/¬^{2}D		1.666	1.462	3.980	5.126	0.489	1.462	4.804	0.507	3.406	0.567
Degree of dominance		0.775	0.827	0.501	0.442	1.429	0.827	0.456	1.405	0.542	1.328
Heritability (NS) %		56.90	54.30	72.35	77.82	23.44	48.63	68.26	23.14	72.59	34.20
Genetic advance		1.64	1.78	28.67	25.69	0.66	0.85	1.90	1.19	5.14	14.81

*, ** Significant at 5% and 1% levels, respectively.

Table 2. Estimates of general combining ability effects of lines and testers for yield and yield attributing traits in maize.

Parents	Days to 50% pollen shed	Days to 50% silk emergence	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (mm)	No. of kernel rows ear^{-1}	Number of kernels row^{-1}	100 kernel weight (g)	Grain yield plant^{-1} (g)
Lines										
PFSR-2	-0.314	-0.314	15.124**	5.333*	0.355	-0.330*	-0.981**	0.171	2.914**	-3.152
PFSR-3	-0.314	-0.248	13.057**	3.267	0.449	-0.430**	-0.248	-0.429	1.114**	8.114**
PFSR-6	-0.181	-0.714**	11.457**	6.667**	0.422	-0.137	-0.914**	-0.362	2.781**	4.248
PFSR-7	0.019	-0.248	4.524	3.333	0.382	-0.650**	-1.314**	0.838	2.314**	-4.152
KML-4	-1.114**	-0.781**	-36.476**	-19.800**	0.002	0.356*	1.819**	0.305	-5.419**	-4.086
KML-79	1.752**	2.352***	-1.21	1.000	-1.558 **	0.536**	0.886**	-3.229**	-0.619	-14.019**
KML-369	0.152	-0.048	-6.476*	0.200	-0.051	0.656**	0.752**	2.705**	-3.086**	13.048**
SE± lines	0.188	0.208	2.647	1.896	0.327	0.161	0.253	0.623	0.38	2.201
Testers	-0.667**	-1.105**	-0.971	8.048**	0.809 **	0.077	-0.257	-0.219	0.381	0.438
KML-80	0.333*	0.514**	-0.781	-9.810**	-0.144	-0.128	-0.495*	-0.029	0.762*	-2.181
KML-370	1.190**	1.038**	5.505*	15.714**	-0.658 *	0.758**	0.790**	-0.457	0.429	20.724**
KML-461	-0.810**	-0.438*	-8.162**	-9.476**	0.528	-0.304*	0.171	1.019	0.048	-9.562**
KML-801	-0.048	-0.01	4.41	-4.476**	-0.534	-0.404**	-0.21	-0.314	-1.619**	-9.419**
KML-802	0.159	0.176	2.237	1.602	0.277	0.136	0.214	0.526	0.321	1.86
SE± testers	-0.314	-0.314	15.124**	5.333*	0.355	-0.330*	-0.981**	0.171	2.914**	-3.152

*, ** Significant at 5% and 1% levels, respectively.

Significant negative heterosis for days to 50% pollen shed and days to 50% silk emergence is an indication of earliness. For days to 50 % pollen shed mean values were in the range of 58.7 to 65.3 days and for days to 50% silk emergence mean values were in the range of 59.7 to 67.3 days. Majority of the crosses showed significant and negative standard heterotic effects over check 30v92 for days to 50% pollen shed (-1.61 to -5.37%) and days to 50% silk emergence (-1.56 to -7.25%). The testers KML-80, KML-801 with all seven lines i.e. PFSR-2, PFSR-3, PFSR-6, PFSR-7, KML-4, KML-79 and KML-369 and tester KML-370 with all the lines except KML-79 and KML-369 showed high negative and significant heterotic values for days to 50% pollen shed and days to 50% silk emergence. Negative heterosis for these characters indicates the possibilities for breeding of maize for earliness and results were in conformity with earlier reports of Avinashe *et al*. (2013) and Saidaiah *et al*. (2008).

Heritability estimates provide information on the transmission of the characters from parents to progenies. Heritability in narrow sense was high for all the characters except ear length, number of kernels row^{-1} and grain yield plant^{-1} in which moderate heritability was noticed (Table

Table 3. Specific combining ability, standard heterosis and *per se* performance of best performing crosses

Character	Crosses	PFSR-2 × KML-461	PFSR-3 × KML-370	PFSR-6 × KML-80	PFSR-7 × KML-80	PFSR-7 × KML-461	KML-369 × KML-802	SE (m) ±
Grain yield plant^{-1} (g)	*sca*	19.676 **	21.648 **	21.895 **	16.629 **	12.010 *	36.952 **	4.921
	het.	5.04	0.44	-0.03	-6.53	0.92	6.62	6.96
	per se	221.00	211.33	210.33	196.67	212.33	224.33	-
Days to 50% pollen shed	*sca*	0.41	-0.067	-0.533	-0.733	-0.924 *	-0.819	0.42
	het.	0.00	-2.15**	-4.31**	-4.31**	-1.61**	-3.23**	0.59
	per se	62.00	60.67	59.33	59.33	61.00	60.00	-
Days to 50% silk emergence	*sca*	0.362	-0.181	-0.762	-0.895	-0.371	-0.857	0.465
	het.	-1.03	-2.58**	-6.74**	-6.22**	-2.07**	-4.14**	0.66
	per se	63.67	62.67	60.00	60.33	63.00	61.67	-
Plant height (cm)	*sca*	7.162	-6.819	2.305	-1.762	-3.571	5.19	5.92
	het.	6.73	-3.29	0.00	-4.93	-2.84	-4.34	8.37
	per se	238.00	215.67	223.00	212.00	216.67	213.33	-
Ear height (cm)	*sca*	1.619	-5.79	2.619	3.286	-2.714	3.943	4.239
	het.	25.70**	-11.27	20.07**	17.25**	19.02**	1.41	6.00
	per se	119.00	84.00	113.67	111.00	112.67	96.00	-
Ear length (cm)	*sca*	-0.355	0.537	0.545	1.251	1.051	0.328	0.732
	het.	-8.29**	-1.44	2.80**	5.86**	-1.76	-6.46**	1.04
	per se	20.10	21.60	22.53	23.20	21.53	20.50	-
Ear girth (mm)	*sca*	-0.031	0.221	0.056	0.57	0.222	1.510 **	0.359
	het.	0.49	-4.00**	-1.97**	-1.97**	0.12	8.92**	0.51
	per se	16.33	15.60	15.93	15.93	16.27	17.70	-
Number of kernel rows ear^{-1}	*sca*	0.41	-0.371	0.057	-0.21	0.41	1.343 *	0.566
	het.	-6.36**	-14.91**	-14.91**	-19.13**	-8.53**	4.23**	0.80
	per se	14.67	13.33	13.33	12.67	14.33	16.33	-
Number of kernels row^{-1}	*sca*	-0.41	1.429	-0.114	1.352	1.590	-1.086	1.392
	het.	-12.20**	-8.12**	-12.20**	-5.68**	-5.68**	-7.32**	1.97
	per se	36.00	37.67	36.00	38.67	38.67	38.00	-
100 kernel weight (g)	*sca*	0.371	0.505	2.886 **	2.352 **	1.638	1.752 *	0.849
	het.	12.38**	8.85**	18.59**	15.94**	14.16**	-5.30**	1.20
	per se	42.33	41.00	44.67	43.67	43.00	35.67	-

*, ** Significant at 5% and 1% levels, respectively.

2). Heritability was in the range of 23.14% to 77.82%. High heritability for number of kernel rows ear^{-1}, number of kernels row^{-1} and 300 kernel weight was reported by Mostafavi *et al*. (2013), where as Winnows *et al*. (2010) reported high heritability for ear length, ear diameter, 100 kernel weight and grain yield.

The crosses showing high heterosis for two or more grain traits also showed high negative heterosis for days to 50% pollen shed and days to 50% silk emergence. It indicates the role of component heterosis in selection of hybrids and the similarities in the inheritance of these traits and distinct possibilities exist to pickup hybrids giving heterosis simultaneously for these characters. The *perse* performance has reflection in highly heterotic crosses. Therefore the *perse* performance of the hybrids needs to be considered in selection in addition to heterotic effects.

Finally, the cross combinations by involving tester KML-80 with lines PFSR-6 and PFSR-7, and line KML-369 with tester KML-802 manifested significant high *sca* effects, excellent heterosis and *perse* performance for yield and yield contributing traits coupled with earliness and hence, these could be effectively exploited by testing in late-wilt prone areas across locations over years.

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Assessment of maize hybrids for grain yield and its contributing characters under well-watered and flowering stress conditions

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ABSTRACT

The experiment was carried out at Agricultural Research Station, Karimnagar, during *rabi* 2014-15. In the present study, twenty single cross maize hybrids were evaluated under well-watered and flowering stress conditions to identify the hybrids for tolerance to flowering stress. Hybrids differed significantly for grain yield and yield contributing characters under both flowering stress and well-watered conditions. Grain yield varied from 1922 to 6102 kg ha^{-1} under flowering stress, and from 5040 to 10000 kg ha^{-1} under well-watered condition. Flowering stress reduced grain yield by 45%. Top 5 yielders under flowering stress produced >5000 kg ha^{-1} and had a yield advantage of >18% over the check DHM-117. Two hybrids namely, BML-45 × BML-32 and BML-32 × BML-15 recorded competitive grain yields both under flowering stress and well-watered conditions.

Keywords: Flowering stress, Grain yield, Maize, Well-watered

In India Maize *(Zea mays* L.) is the third most important cereal crop after rice & wheat. In 2013-14, it was grown in area of 9.06 mha with production of 24.25 mt and productivity of 2680 kg/ha (Centre for Monitoring Indian Economy, 2014). In Telangana state also, it is the third most important crop after Cotton and Rice and maize was cultivated in an area of 4.66 lakh hectares during 2014. In recent years in the state, 30-40% deficit rainfall was received from South-West monsoon, a major monsoon of the state. The yields were drastically reduced as the crop suffered severe stress at flowering stage, the most sensitive stage of the crop to limiting water stress. It has been estimated that about one third of the world's potentially arable land suffers water shortage and crop yields are often reduced by drought (Khan *et al*., 2004). Breeding genotypes for drought and salinity is much required across the world (Denby and Gehring, 2005). Drought remains the most important devastating factor in Maize and it has different effects on the crop depending on the growth stage at which it occurs (Umar *et al*., 2015). Soil moisture deficit drastically reduce the yield, especially if it occurs during the reproductive phase (NeSmith and Ritchie, 1992; Basseti and Westgate, 1993). Drought stress or water deficit is an enviable and recurring feature of World Agriculture. It can be devastating if it occurs for a long period, especially during flowering. The main purpose of the present investigation was to assess the performance of maize hybrids to flowering stress.

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MATERIALS AND METHODS

Ten promising inbred lines collected from Maize Research Centre, ARI, Rajendra nagar, Hyderabad were involved in crossing programme during kharif, 2014 and the effective twenty crosses were evaluated against standard public bred check DHM-117 in *rabi* 2014-15. Experimental material was evaluated both under well-watered and flowering stress condition (suspending the irrigation 20 days before flowering). The experimental material was sown in randomized block design with two replications in each condition. Each genotype was sown in a row of 4 m length spaced 75 cm apart with a 20 cm distance between plants with in the row. All the recommended agronomic practices and plant protection measures were taken up in time to raise the crop.

For each condition, growth and yield parameters i.e. plant height; ear height, kernel rows, kernels per row, ear length; ear girth and shelling percentage were recorded on five randomly selected plants in each entry in each replication. The grain yield was determined as cob yield (kg ha^{-1}) × shelling percentage. For each moisture zone, ANOVA was carried out using standard statistical procedures (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

Hybrids differed significantly for grain yield and yield contributing traits under both flowering stress and well-watered conditions, except for ear length under well-watered conditions and shelling percentage under flowering stress conditions (Table 1) Results indicated the variation in the grain yield performance of hybrids in both the environments and suggested that it would be more appropriate to select superior maize hybrids suitable to particular environment. For grain yield, seven out of twenty hybrids recorded significantly superior over the check DHM-117 under well-watered conditions whereas under flowering stress conditions, except three all recorded significant superior yields over the check DHM-117 (Table 2). BML-32 × BML-15 recorded a grain yield of 10000 kg/ha and 5540 kg/ha under well-waterd and flowering stress conditions, respectively. Similarly, BML-45 × BML-32 recorded a grain yield of 9963 kg/ha under well-watered conditions and 4441 kg/ha under flowering stress conditions. Under flowering stress, yield reduction of hybrids was in the range of 18.6 to 75.3% as that of well-watered condition. Similarly, Mory *et al.*, (2014) reported 56.41% mean yield reduction under drought stress over non-stress across four environments. 23% of yield reduction under drought over well-watered conditions was reported by Adebayo *et al.*, (2014). A range of 20 to 30% yield reduction was termed as severe drought stress by Banziger *et al.*, (2000). In two hybrids BML-45 × BML-13 (18.6%) and BML-15 × BML-13 (21.6%), the reduction in yields was low under flowering stress conditions as against well-watered conditions. Over the mean, only three hybrids BML-45 × BML-13 (5342 kg/ha), BML-45 × BML-2 (6102 kg/ha) and BML-32 × BML-15 (5540 kg/ha) recorded significantly superior yields under flowering stress conditions. For all the yield contributing characters except ear girth, two hybrids BML-45 × BML-32 and BML-32 × BML-15 showed either significantly superior or comparable performance to the check DHM-117 under well-watered and flowering stress conditions.

BML-32 × BML-15 was found to be superior over the check DHM-117 for yield and yield contributing characters and large scale testing of this hybrid on farmer's fields in drought prone areas is required.

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Table 1. Analysis of variance for yield and yield traits in maize under well-watered and flowering stress conditions.

Source	d.f.	Mean sum of squares							
		Plant height (cm)		Ear height (cm)		Ear length (cm)		Ear girth (cm)	
		WW	FS	WW	FS	WW	FS	WW	FS
Replications	1	91.52	1184.02	106.88	933.43	31.04	6.02	0.01	0.60
Treatments	20	730.52**	368.58**	365.27**	231.91**	21.46	5.14**	0.16*	0.15**
Error	20	39.22	29.7	28.18	7.98	18.25	0.24	0.06	0.03

***Table 1** cont....*

Source	d.f.	Mean sum of squares							
		Kernel rows		Kernels per row		Shelling percentage		Grain yield (kg ha^{-1})	
		WW	FS	WW	FS	WW	FS	WW	FS
Replications	1	0.02	0.15	11.42	0.92	3.64	13.54	194168.27	5881.17
Treatments	20	1.98**	1.00**	16.08*	21.63**	22.57**	19.08	3123296.20**	2938633.06**
Error	20	0.47	0.26	6.81	1.50	3.97	18.56	389230.36	334445.92

WW- Well-watered; FS- Flowering stress

Table 2. Performance of maize hybrids for yield and yield attributing characters under well-watered and flowering stress conditions.

Hybrid	Plant height (cm)		Ear height (cm)		Kernel rows		Kernels per row		Ear length (cm)		Ear girth (mm)		Shelling (%)		Grain yield /ha (kg)		% yield reduction
	I	D	I	D	I	D	I	D	I	D	I	D	I	D	I	D	
BML-51 × BML-45	207.5	177.0	98.5	79.5	13.6	14.5	27.1	27.1	16.5	16.6	4.6	4.5	75.8	78.3	6467	4309	33.4
BML-51 × BML-2	218.5	183.0	118.0	89.5	12.2	12.4	31.2	30.7	17.9	17.3	4.5	4.2	78.3	78.8	6083	3827	37.1
BML-45 × BML-32	192.0	164.0	90.0	71.0	15.0	14.2	31.7	31.6	19.4	17.9	4.8	4.3	80.1	80.7	9963	4441	55.4
BML-45 × BML-15	207.0	184.0	107.0	84.0	13.4	14.3	30.1	30.6	18.1	17.5	4.4	4.3	76.0	74.2	7617	3441	54.8
BML-45 × BML-14	166.5	158.0	79.5	72.0	13.4	13.2	25.0	22.8	14.7	12.7	4.5	3.8	81.5	80.2	5040	3074	39.0
BML-45 × BML-13	149.5	152.5	69.5	66.0	14.6	14.2	28.5	28.1	31.5	17.0	4.6	4.4	82.1	81.7	6560	5342	18.6
BML-45 × BML-10	178.5	141.5	90.5	64.5	14.6	13.4	24.7	26.7	15.4	16.5	4.7	4.4	77.0	77.3	7170	2468	65.6
BML-45 × BML-7	191.5	159.5	92.5	71.5	13.0	14.0	24.7	27.8	16.5	16.9	4.6	4.5	73.7	77.5	6484	4858	25.1
BML-45 × BML-6	189.0	159.5	88.5	68.0	15.2	14.4	28.9	25.0	18.3	14.3	4.7	4.3	78.1	75.0	6810	3919	42.5
BML-45 × BML-2	196.5	162.5	97.0	68.5	13.8	13.0	31.1	27.7	18.1	17.2	4.5	4.5	83.4	84.5	8490	6102	28.1
BML-32 × BML-15	232.5	163.0	119.0	66.0	14.6	13.1	35.6	27.6	18.7	18.3	4.7	4.6	81.8	80.1	10000	5540	44.6
BML-32 × BML-2	215.0	149.5	101.0	69.0	13.6	12.6	28.2	33.8	18.2	18.9	4.6	4.5	83.5	82.1	7213	5213	27.7
BML-15 × BML-13	181.5	147.5	89.0	70.5	13.4	13.9	30.2	26.8	17.0	17.6	4.5	4.6	77.8	80.8	6617	5185	21.6
BML-15 × BML-10	214.0	178.0	121.5	95.0	13.4	14.2	30.2	25.0	18.2	15.1	4.6	4.1	76.6	77.2	8133	2011	75.3
BML-15 × BML-7	213.0	167.5	114.0	79.5	14.2	14.2	31.1	35.0	17.0	18.6	4.6	4.2	76.8	77.3	7150	1922	73.1
BML-15 × BML-6	218.0	198.5	117.0	106.0	13.6	12.8	30.2	27.8	18.1	14.6	4.7	4.0	73.8	75.6	6267	4531	27.7
BML-14 × BML-2	195.0	161.5	100.5	75.0	13.6	12.6	31.2	29.5	19.5	17.7	4.8	4.5	79.4	75.1	8557	4515	47.2
BML-10 × BML-2	194.0	158.5	101.0	70.5	13.6	12.8	31.6	25.0	17.3	14.3	4.8	4.0	77.3	76.7	7000	2195	68.6
BML-7 × BML-2	206.5	169.0	102.5	83.0	13.4	13.7	29.6	23.8	17.0	16.5	4.7	4.2	77.6	77.1	6530	5000	23.4
BML-6 × BML-2	192.5	154.5	96.0	67.5	16.6	12.9	27.3	23.8	16.8	15.5	5.2	4.5	76.3	74.1	7753	3610	53.4
DHM-117 (Check)	189.5	167.5	90.0	82.5	15.6	14.2	34.2	24.5	19.6	16.8	5.7	5.0	70.1	71.9	8690	3596	58.6
Mean	197.5	164.6	99.2	76.1	13.4	13.5	29.6	27.6	18.3	16.5	4.7	4.3	77.9	77.9	7362	4052	45.0
C.D.	13.2	11.5	9.2	5.9	1.4	1.1	5.5	2.6	1.9	1.0	0.5	0.3	4.2	3.8	1311	1215	-
C.V. (%)	3.2	3.3	5.2	3.7	4.9	3.7	8.8	4.43	2.5	3.0	5.2	3.7	2.6	5.5	8.5	14.3	-

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Genetic evaluation of yield and its component traits in maize hybrids (*Zea mays* L.) using generation mean approach

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ABSTRACT

The study conducted at the Maize Research Station, Sardarkrushinagar Dantiwada Agricultural University, Bhiloda, India during the *rabi* season of 2012, 2013 and *kharif* 2014. The research aimed to evaluate genetic parameters for grain yield per plant, ear length, ear girth, number of row per ear and number of grains per row using generations mean analysis of three yellow maize hybrids (VL 109178 x HY10R-N10235-235, VL 109178 x HY10R-N10235-257 and HY10R-N10235-260 x VL 1032)) to detect epistasis ,estimates of m, d, h, i, j and l parameters, potence ratio, heterosis and inbreeding depression. Treatments were arranged in a Randomized Complete Block Design with two replications. Results showed that the additive-dominance model was adequate to demonstrate the genetic variation and its importance in the inheritance of most studied traits. Non-allelic gene interaction was operating in the control of genetic variation in most studied traits. The signs of [h] and [l] were distributed equally in opposite and same direction in most studied traits for the all three crosses. Also, the inheritance of all quantitative traits was controlled by additive and non-additive genetic effects, but dominance gene effects play the major role in controlling the genetic variation of the most studied traits under investigation, suggesting that the improvement of those characters need intensive selection through later generations. Highly significant heterosis relative to mid and better parents was found for all characters, correlated that with inbreeding depression for all traits. Potence ratio for most of the traits exceeded the unity indicating the importance of types of epistatic gene action.

Keywords: Gene action, Heterosis Maize and Potence ratio

Maize is the world's most widely grown cereal and is the primary staple food in many developing countries (Morris *et al.*, 1999). It is a versatile crop with wider genetic variability and able to grow successfully throughout the world covering tropical, subtropical and temperate agro-climatic conditions Globally, India ranks 4th in area and 7th in production of maize. The area, production and productivity of maize in India is 8.93 m ha, 21.57 mt and 2.50 t/ha, respectively during 2011-12 (Anonymous, 2013). Grain yield is the most important quantitative and complex trait in maize. This means that yield expression is caused, not only by genetic factors, but also by environmental and genotype x environment interaction effects. Melchinger *et al*. (1986) described about the nature of gene action allows which maize breeders to optimize their breeding programs. The choice of selection and breeding procedures for genetic improvement of maize or any other crop depends largely on the knowledge of type of gene action for different characters in the plant materials under investigation. Generation mean analysis, a biometrical method developed by Mather and Jinks (1982), is a useful technique for determining gene effects for polygenic traits. Its greatest merit lies in the ability to estimate epistatic gene effects such as additive × additive [i], additive x dominance [j] and dominance × dominance [l] interactions (Singh and Singh, 1992). Therefore, availability of good knowledge of these genetic parameters existing in different yield contributing characters and the relative proportion of this genetic information in various quantitative traits is a pre-requisite for effective crop improvement.

Thus, study was undertaken with the aim to obtain useful information, and evaluate gene action involved in the inheritance of grain yield and some agronomic characters as well as potence ratio, heterosis and inbreeding depression in three different crosses in maize.

MATERIALS AND METHODS

The field experiment was conducted at the Maize Research Station, Sardarkrushinagar Dantiwada

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Agricultutral University, Bhiloda, India during the *rabi* growing seasons of 2012, 2013 and 2014.The five early maturing parental lines; VL 109178, HY10R-N10235-235, HY10R-N10235-257, HY10R-N10235-260 and VL 1032) received from CIMMYT, Hyderabad (Table 1) were intercrossed to produce the three high yielding F_1 crosses *i.e.* VL 109178 x HY10R-N10235-235 (Cross 1) VL 109178 x HY10R-N10235-257(Cross 2) and HY10R-N10235-260 x VL 1032(Cross 3). In the second season 2013, F_1 plants of each cross were selfed and backcrossed to the three parents to obtain F_2, BC_1 and BC_2 generations respectively. The six populations, *i.e.* P_1, P_2, F_1's, F_2, BC_1 and BC_2 of the three maize crosses were grown in third season (2014) in a randomized complete block design with two replicates in 4 m long row with 70 x 20 cm spacing. The six populations of each cross were planted in ten rows, *i.e.* one row for each of P_1, P_2 and F_1, two rows for each of BC_1 and BC_2, and four rows for F_2 generation. Observations were recorded on ear length (cm), ear girth (cm), number of rows per ear, number of grains per row and grain yield per plant (g).

To determine the presence or absence of non-allelic interactions, scaling test as suggested by Mather (1949) and Hayman and Mather (1955) was used. Scaling tests A, B and C and their variance have been calculated to test adequacy of the additive-dominance model in each case. The A and B scaling tests provide the evidence for the presence of additive x additive (i), additive x dominance (j) and dominance x dominance (l) type gene interactions. The C scaling test provide a test for type l epistasis. The type of epistasis was determined only when dominance (h) and dominance x dominance (l) effects were significant; when these effects had the same sign the effects were complementary while different signs indicated duplicate epistasis (Kearsey and Pooni, 1996).

$A = 2BC_1 - P_1 - F_1$, $B = 2BC_2 - P_2 - F_1$, $C = 4F_2 - 2F_1 - P - P_2$

The six parameters of the genetic model (m, d, h, i, j and l) were computed according to Jinks and Jones (1958) where: $m = F_2$, $d = BC_1 - BC_2$,

$h = F_1 - 4F_2 - 0.5P_1 - 0.5P_2 + 2BC_1 + 2BC_2$,
$i = 2BC_1 + 2BC_2 - 4F_2$,
$j = BC_1 - 0.5P_1 - BC, + 0.5P_2$,
$k = P_1 + P_2 + 2F_1 + 4F_2 - 4BC_1 - 4BC_2$

Smith (1952) approaches were used to estimate Potence ratio (P) as follows:

$P = (F_1 - MP) / [0.5 \times (P_2 - P_1)]$ where: F_1 = the first generation mean, P_1 = the mean of the first parent, P_2 = the mean of the better parent and MP = mid parents value. Complete dominance is indicated when potence ratio is equal to (+1) or (-1). Partial dominance is the case when ratio between (+1) and (-1). Over-dominance indicated if ratio exceeds (± 1).

Heterosis was expressed as the percentage deviation of F_1 mean performance from mid-parents and better parent according to Singh and Chaudhary (1977) as follows:

$HMP = [(F_1 - MP) / MP] \times 100$ and $HBP = [F_1 - BP) / BP] \times 100$

Inbreeding depression (%) were estimated according to Singh and Chaudhary (1977) as follows:

$$ID = [(F_1 - F_2) / \times 100$$

RESULTS AND DISCUSSION

The means and variance of six generations of three crosses for five traits are presented in Tables 2. The results indicated that hybrids performed better than their respective parents in the entire three cross except ear length and number of grains per row in second cross showing inferior performance than their respective parental generations. In general, however the trait mean values for all the F_1 and F_2 generations were higher than corresponding values for BC_1 and BC_2 generations, as well as, the transgressive segregation for all traits was also observed in the F_2 generation. The results are in confirmation with the results obtained by Shahrokhi *et al.* (2011) and El-Badawy (2012).

Table 1. Parental lines with their pedigree

Parent	Pedigree
VL 109178	P31C4S5B-23-##-4-B*7-4-BBB
HY10R-N10235-235	G18seq C5F100-1-1-3-1-2-B/(DT/LN/EM-46-3-1 x CML311-2-1-1-3)-B-F203-1-1)-B-B-7-B
HY10R-N10235-257	(DTPWC9-F5-4-1-1-2-2-1-1—B/(DT/LN/EM-46-3-1 x CML311-2-1-3)-B-F203-1-1)-B-B-1-B
HY10R-N10235-260	(DTPWC-F2-3-1-1-2-1-2-1-B/WLS-F36-4-2-2-B0-B-B-1-B
VL 1032	CA14507-BB-2-BBB

Table 2. Mean and their standard error of six generations with three crosses for five traits in maize

Generation mean and trait	Cross 1	Cross 3	cross 4
Grain Yield(g)			
P_1	55.9±2.52	41.50±2.34	38.40±2.26
P_2	65.5±2.50	72.30±2.98	47.0±2.42
F_1	136.7±5.16	145.805.68	160.30±5.18
F_2	74.80±4.55	74.97±3.50	130.17±8.72
B_1	61.50±4.09	77.00±7.40	102.35±10.51
B_2	63.0±4.71	97.05±5.58	90.30±10.07
Ear Length (cm)			
P_1	10.65±0.39	25.00±13.52	10.10±0.63
P_2	12.65±0.35	13.33±1.19	13.60±1.12
F_1	15.90±0.25	15.39±0.68	18.50±0.94
F_2	12.22±0.31	13.22±0.36	15.40±1.00
B_1	11.50±0.37	12.45±0.62	13.20±0.89
B_2	11.20±0.50	14.10±0.60	14.75±0.76
Ear Girth(cm)			
P_1	11.82±0.17	12.32±0.78	11.15±0.44
P_2	12.02±0.36	11.82±0.47	12.20±0.35
F_1	13.60±0.23	13.12±0.88	15.00±0.51
F_2	14.55±3.86	11.80±0.30	13.15±0.37
B_1	12.10±0.20	12.45±0.33	13.00±0.35
B_2	11.45±0.21	12.40±0.21	12.05±0.24
No. of Grains Row/ear			
P_1	10.20±0.50	14.20±1.67	12.40±0.56
P_2	10.0±0.55	22.10±2.09	10.0±0.00
F_1	11.40±0.60	30.80±2.42	12.10±0.68
F_2	10.65±0.27	28.37±0.83	13.25±0.42
B_1	11.20±0.55	25.05±1.32	14.15±0.43
B_2	10.40±0.38	27.25±1.72	12.25±0.56
No of grains/row			
P_1	21.60±1.62	23.10±3.42	17.40±2.15
P_2	22.30±0.79	10.40±0.56	21.90±2.45
F_1	35.80±0.46	10.80±0.46	34.70±1.53
F_2	26.62±1.21	11.70±0.27	32.45±2.02
B_1	23.70±1.06	12.60±0.45	28.85±1.74
B_2	23.55±1.50	11.70±0.42	30.60±2.11

Gene effects

The results of the A, B, and C scaling tests for assessing the validity of additive - dominance models are given in Table 3. The non-allelic interaction was found to be operating in the control of genetic variation among the six generations for most studied traits. The values of the A, B and C scaling tests were not significant in the first cross for grain row per ear as well as ear length and girth in second cross indicating the absence of non-allelic interaction and the additive - dominance model was adequate to demonstrate the genetic variation and it is important in the inheritance of this studied trait in such cross. These results are in agreement with those obtained by Ishfaq (2011).

The estimates of the six parameters, *i.e.* additive [*d*], dominance [*h*], additive × additive [*i*], additive x dominance [*j*] and dominance x dominance [*l*] and means [*m*] are presented in Table 3. The mean effects were highly significant for all studied traits in all the three crosses, indicating that these traits are quantitatively inherited. Additive effects [*d*] were significant only for ear girth in first cross, grain yield and ear length in second cross and ear girth and grains per row in third cross. As shown in Table 3, some of the additive effects were negative. The negative or positive signs for additive effects depend on which parent is chosen as P_1. Perusal of the Table 3 showed that non additive genetic effects and maximum number of dominant genes were controlling the mechanism of inheritance of all the traits in all three crosses due to significant dominance estimate [h] except cob girth (first cross), cob length (second cross) and grain yield in third cross which showed negative values. With regard to the negative value [*h*] observed for some studied traits indicated that the alleles responsible for less value of traits were over dominant over the alleles controlling high value (Cukadar-Olmedo and Miller, 1997). The dominance gene effect was higher than additive gene effect for all studied traits indicating predominant role of dominant component of gene action in inheritance of these traits, so the selection for these traits should be delayed to later generation when dominant effect is diminished. These results are in agreement with Sofi *et al*. (2006); Iqbal *et al*. (2010); El-Badawy (2012) and Shahrokhi *et al*. (2013) whereas additive type of genetic effect was reported by Ma *et al*. (2007) which is in contradiction the present study.

As it is shown in Table 3, different types of epistasis interaction effects were found for different traits and crosses, with the exception of ear height in the first cross, as well as, ear diameter and number of kernels per row in the second cross. Our results showed that, besides the additive and dominance genetic effects, epistatic components have also contributed to genetic variations for most of the characters studied. However, their relative magnitudes vary for different traits. In such a situation, the appropriate breeding method is the one that can effectively exploit the three types of gene effects simultaneously. These results are in accordance with the

Table 3. Mean ± standard error and scaling test and genetic effects for different traits of maize

Cross	A	B	C	m	d	h	i	j	l	Type of epistatis
Cross 1										
Grain yield (g)	69.60*±7.07	75.60*±7.80	95.60*±15.03	74.80*±3.22	-1.80±4.41	26.40±16.09	-9.60*±15.60	6.0±9.17	194.80*±23.18	C
Ear length (cm)	3.55*±0.62	6.15*±0.78	6.20*±1.02	12.22*±0.22	0.30±0.44	0.75±1.22	-3.50±1.26	2.60*±0.97	13.20*±2.06	C
Ear girth(cm)	1.22±0.35	2.72*±0.43	-7.16±10.95	14.55*±2.73	0.65*±0.21	-9.24±10.95	-11.10±10.95	1.50*±0.50	15.04±10.98	D
Grains row/ear	-0.80±0.97	0.60±0.80	0.40±1.27	10.65*±0.19	0.80±0.48	1.90±1.33	-	-	-	
No. of grains/row	10.0*±1.92	11.0*±2.22	9.00*±3.47	26.62*±0.79	0.15±1.30	1.85±4.15	-12.0*±4.10	1.0±2.90	33.0*±6.26	C
Cross 2										
Grain yield (g)	33.30*±11.33	24.00*±9.10	105.50*±13.09	74.97*±2.47	-20.0*±6.55	137.10*±16.97	48.20*±16.43	-9.30±13.38	9.10*±0.31	C
Ear length (cm)	16.05±9.61	1.08±1.29	17.33±9.70	13.22*±0.25	-1.65*±0.61	-3.01±5.08	-	-	-	
Ear girth (cm)	0.52±0.95	0.12±0.77	3.14±1.64	11.80*±0.21	0.05±0.28	3.53*±1.23	-	—	-	
Grain row/ear	-5.10±2.80	-1.60±3.33	-15.60*±4.58	28.37*±0.59	-2.20±1.54	3.75±4.35	-8.90*±3.88	3.50±3.61	2.20±7.68	C
No. of grains/row	8.70*±2.52	-2.20*±0.79	8.30*±2.65	11.70*±0.19	0.90±0.43	-4.15*±1.73	1.80±1.17	-0.90±2.60	4.70*±1.18	D
Cross 3										
Grain yield (g)	-6.00±15.40	26.70±14.80	-14.70*±25.88	130.17*±6.16	12.05±10.29	-17.80±32.37	-35.0*±32.14	32.70±20.72	156.1*±48.63	D
Ear length (cm)	2.20±1.49	2.60±1.49	9.0*±3.27	15.40±*0.71	-1.55±0.82	0.95±3.38	-5.70±3.29	0.40±1.89	10.50*±4.65	C
Ear girth(cm)	0.15±0.69	3.10*±0.55	0.75±1.33	13.15*±0.26	0.95*±0.30	0.82±1.28	-2.50*±1.21	2.95*±0.72	5.75*±1.80	C
Grains row/ear	-3.80*±0.88	-2.40*±0.92	-6.40*±1.60	13.25*±0.30	1.90*±0.50	0.70±1.66	-0.20±1.57	1.40±1.08	-6.00*±2.57	D
No. of grains/row	-5.60*±3.09	-4.60*±3.62	-21.0*±6.54	32.45*±1.43	-1.75±1.93	4.25±7.09	-10.49±6.91	1.00±4.50	0.60±10.14	C

*Significant at 0.01% P level C= complementary D= Duplicate findings of Jebaraj *et al.* (2010), Khodarahmpoor (2011), Sher *et al*. (2012) and Haq *et al*. (2013).The signs associated with estimates of [*i*], [*j*] and [*l*] types of epistasis indicate the direction in which the gene effect influence the mean of the population (Mather and Jinks, 1982). For different traits in three crosses *viz.*, ear girth, grains row per cob number of grains per row, signs of the estimates of [*l*] were opposite to that of [*h*] indicating duplicate epistasis suggesting the possibilities of obtaining trangressive sergeants in the later generation. More over duplicate type of epistatis is unfavourable from the breeders point of view because of its decreasing effect on the analyzed trait (Zdravkovik *et al*., 2000). This result is supported by the findings of Haq *et al*. (2013). On the other side, grain yield per plant, no. of grains per row and ear length in the first cross, grain yield and grain row per ear in the second cross and ear length and girth revealed same sign of [*h*] and [*l*] components indicated presence of complimentary type of gene action for these traits. Thus, these traits can be exploited through heterosis breeding. Similar results for the traits were reported by El-Mouhamady *et al*. (2013).

Potence ratio, heterosis and inbreeding depression

Potence ratio, heterosis and inbreeding depression in the three crosses are given in Table 4. Potence ratio was calculated to determine the nature and degree of dominance for all studied characters. The results indicated that potence ratio values exceeded the unity in most of the studied traits except number of grain rows per ear for the cross one and three, for ear girth and grains per row in cross two indicating importance of type of epistatis gene action. Over dominance towards the higher parent was detected for most studied traits. Generally, potence values followed the same trend as heterotic effects for most of the traits. These results are in accordance with those obtained by El-Badawy (2012) and Wannons *et al.* (2015).

It is evident from Table 4 that highly significant positive heterosis relative to mid and better parent for most studied traits was present in the three crosses, indicating that dominance direction was toward the best parent, with exception for ear girth and length in cross one and two respectively which showed highly significant negative heterosis relative to mid and better parent indicating that dominance direction was toward the low respective parent. It is worth noting that heterotic effect for grain yield per plant was larger in magnitude than for any one of its components which is logically expected. High heterosis for grain yield was also observed by Rajitha *et al.* (2014). The results of heterosis suggested that hybrid vigour is available for the commercial production of maize and selection of desirable hybrids among the crosses having heterotic and heterobeltiotic effects yield contributing characters is the best way to improve the grain yield of maize. The significance of heterotic effects showed that non-additive genetic type of gene action was important

Table 4. Potence ratio, Heterosis and Inbreeding Depression in three crosses of maize

Trait	Cross	Potence ratio	Heterosis (%) over		ID (%)
			MP	BP	
Grain yield (g)	Cross 1	15.83	117.1735	85.34351	45.28
	Cross 2	5.77	174.2169	57.39972	48.57
	Cross 3	27.34	317.4479	241.0638	18.78
Ear length (cm)	Cross 1	4.25	49.29577	25.6917	23.11
	Cross 2	0.55	-36.16	-67.817	17.05
	Cross 3	3.80	83.16832	36.02941	16.75
Ear girth (cm)	Cross 1	16.80	-4.41176	-4.99168	-6.98
	Cross 2	-4.12	6.331169	6.598985	9.92
	Cross 3	6.33	34.52915	22.95082	12.33
No. of grains row per ear	Cross 1	-13.0	11.76471	14	6.57
	Cross 2	3.203	116.9014	39.36652	7.87
	Cross 3	-0.75	-2.41935	-3	-9.50
No of grains per row	Cross 1	39.57	65.74074	58.40708	25.62
	Cross 2	0.93	-53.2468	-118.269	-8.33
	Cross 3	6.68	99.42529	58.44749	6.55

for such traits. These results were previously reported by Subramanian and Subbaraman (2006), Escorcia-Gutierrez *et al*. (2010) and Wannows *et al.* (2015).

Values of inbreeding depression which are presented in Table 4 were positive for all studied traits in the all three crosses, except for ear girth and number of grain rows. As it is well known both heterosis and inbreeding depression effects are coincides is a particular phenomenon (Falconer 1981 and Mather and Jinks 1982), therefore, it is logically right to expect that heterosis in F_1 will be followed by an appreciable reduction in the F_2 performance and vice versa due to the direct effect of homozygosis. These results have harmony with previous results obtained by Cleso Antônio Patto Pacheco (2002), Escorcia-Gutierrez *et al*. (2010), El-Badawy (2012) and Kumar *et al*. (2014).

Complex genetic behavior was observed for the traits examined in the present study. Conventional selection procedure in the early segregating generation may not play significant role for the improvement of these traits. The complex genetic behavior, particularly additive and dominance components could be successfully exploited by selection in later generations. It is suggested that selection for the improvement of the traits under question should be delayed to later generation of segregating population in maize.

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Knowledge and adoption level of farmers about scientific cultivation of maize in Panchmahal and Dahod District

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ABSTRACT

The study was conducted in Panchmahal and Dahod districts of middle Gujarat Agro climatic Zone-III Morva Hadaf, Santrampur, Limkheda, Devgadhbaria and Dhanpurtalukas were selected purposively as the majority of farmers in these talukas are growing maize as main crop in *kharif* season. Twenty villages were selected from these five talukas by simple random sampling techniques. A list of 200 maize growers was prepared from the selected villages. Ten respondents were selected from each village by proportionate random sampling technique. Thus, total numbers of respondents were 200. The data were tabulated, analyzed and interpreted in the light of the objectives. Majority of the respondents was in middle age group having illiterate to primary education, less participation in social activities, had annual income up to Rs. 10000 to Rs. 20000/- were engaged in Farming + Animal Husbandry + Labour work as main occupationpossessed 1.01 to 4.00 ha of landwere found to have medium levels of economic motivationand medium levels of knowledge on maize production technology.

Keywords: Adoption, Knowledge, Maize

In Panchmahalsand Dahod districts, maize is grown as main crop and cultivated in approximately 2.70 lakh hectare area in *kharif* season. Research scientists, extension workers and farmers have responsibilities to maximize the production and productivity of maize in per unit area. The productivity of maize in the state at present is 1300 kg ha^{-1}. It is less than the national average (2300 kg ha^{-1}) and world average (5500 kg ha^{-1}), respectively. The low productivity in maize was due to lack of scientific cultivation knowledge, poor nutrient management and lack of knowledge on insect-pests and disease management. Keeping all these views, the research study "Adoption of scientific cultivation of maize in middle Gujarat agro climatic zone-III" was taken with following objectives.

- To study the adoption of different scientific cultivation method of maize in middle Gujarat.
- To study the performance of different patterns adopted in relation to in terms of economic return by tribal farmers.

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METHODOLOGY

The study was conducted in tribal areas of Panchmahal and Dahod district of the Gujarat state. Five tribal Talukas were selected and Total 20 village were selected randomly from these talukas. Ten tribal farmers were selected from each village. This constituted total sample of 200 tribal farmers. The data were collected by personal interview technique.

RESULTS AND DISCUSSION

Distribution of respondents according to their personal characteristics from the data presented in Table 1 show that majority (53.50 percent) of the respondents was in middle age group followed by 40.00 percent of the respondents belonging old age group and only 6.50 percent were under young age group.

Table 1. Distribution of maize growers according to age (n=200)

Age group	Number	Percent
Young age (Up to 30 year)	13	6.50
Middle age (31 to 50 year)	107	53.50
Old age (Above 50 year)	80	40.00
Total	200	100.00

Table 2. Distribution of maize growers according to their level of education (n=200)

Level of education	Number	Percent
Illiterate	72	36.00
Primary education (Up to VII Std.)	68	34.00
Secondary education (VIII to X Std.)	38	19.00
Higher Secondary education (XI to XII Std.)	15	7.50
College and above education	07	3.50
Total	200	100.00

A perusal of data presented in Table 2 reveal that majority (36.00 percent) of the respondents were illiterate followed by 34.00, 19.00, 7.50 and 3.50 percent were primary school level, secondary school level, Higher secondary level and college level education respectively. This information gives indication that the literacy rate in tribal area is still very low.

Table 3. Distribution of maize growers according to their social participation (n =200)

Social participation	Number	Percent
No membership	165	82.50
Membership in one organization	21	10.50
Membership in more than one organizations	11	5.50
Holding position	3	1.50
Total	200	100.00

The data in Table 3 revealed that majority (82.5 percent) of the respondents were not participated in any social activity followed by 10.50 percent in one activity and 5.50 percent engaged in more than one activity.

Table 4. Distribution of soybean growers according to their size of land holding (n =200)

Land holding	Number	Percent
Marginal farmers (Up to 1.00 ha)	34	17.00
Small farmers (1.01 to 2.00 ha)	74	37.00
Medium farmers (2.01 to 4.00 ha)	84	42.00
Large farmers (Above 4.00 ha)	8	4.00
Total	200	100.00

It is evident from the data in Table 4 revealed that 42.00 percent farmers possessed 2.01 to 4.00 ha of land followed by 37.00 percent having 1.01 to 2.00 ha of land and 17.00 percent having land up to 1.00 ha. While only 4.00 percent having above 4.00 ha of land.

Table 5. Distribution of maize growers according to their cropping intensity (n =200)

Cropping intensity	Number	Percent
100	34	17.00
200	76	38.00
233	47	23.50
300	29	14.50
400	7	3.50
500	6	3.00
700	1	0.50
Total	200	100.00

It is revealed from Table 5 that 38.00 percent farmers are growing crop twice in a year. While 23.50 percent having 233 percent cropping intensity. 14.50 percent farmers having 300% cropping Intensity. While 17.00 percent farmers having 100percent cropping intensity.

Table 6. Distribution of maize growers according to their occupation (n =200)

Occupation	Number	Percent
Only farming	03	1.50
Farming + Animal Husbandry	79	39.50
Farming + Animal Husbandry + Labour work	65	32.50
Farming +Animal Husbandry + Service	53	26.50
Total	200	100.00

The data presented in Table 6 showed that 39.5 percent farmers possessed f farming and animal husbandry as an occupation, while 32.5 percent farmers had farming and Animal husbandry with labour work also. Further 26.5 0 percent farmers opted for farming and animal husbandry along with job in private public sector, while o only 1.5 percent farmers had only farming as an occupation.

It is apparent from Table 7 that more than half (56.00 percent) of the farmers had annual income up to Rs.10001

Table 7. Distribution of maize growers according to their annual income (n =200)

Annual income	Number	Percent
Less than 20,000	51	25.50
20,000 to 30,000	07	3.50
31,000 to 50,000	84	42.00
50,000 to 70,000	41	20.50
70,000and above	17	8.50
Total	200	100.00

Table 8. Adoption of improved farm technology of maize crop

Practices	Particular	No. of respondents	Percent
Improved variety	University Recommended Varieties		
	1. Gujarat Maize-2	16	8.00
	2. Gujarat Maize-4	10	5.00
	3. Gujarat Maize-6	55	27.50
	4. Narmada Moti	15	7.50
	5. HQPM-1	12	6.00
	Private varieties	35	17.50
	Deshi varieties	57	28.50
Seed rate	Below adoption	0	0.00
	As per recommendation	100	50.00
	Over adoption (up to 20 per cent)	55	27.50
	Over adoption (More than 20 per cent)	45	22.50
Seed treatment	Used readymade treated seed	130	65.00
	Treated in correct way by own & used	70	35.00
Use of culture	Non-adoption	130	65.00
	Treated in correct way	70	35.00
System of sowing	Drilling	03	1.50
	Dibbling (Recommendation)	197	98.50
Time of	Earlier than recommended time	0	0.00
	As per recommended time	200	100.00
	Later than recommended time	0	0.00
Row spacing	30*10	17	8.50
	30*15	02	1.00
	45*10	15	7.50
	45*15	23	11.50
	45*20	17	8.50
	45*25	01	0.50
	60*10	01	0.50
	60*15	16	8.00
	60*20 (Recommendation)	87	43.50
	60*25	01	0.50
	75*10	01	0.50
	75*15	08	4.00
	75*20	10	5.00
	75*25	03	1.50
Thinning days after sowing of maize	15 days	94	47.00
	20 days	31	15.50
	25 days (Recommendation)	48	24.00
	30 days	27	13.50
Earthing up after sowing of maize	30 days	120	60.00
	40 days (Recommendation)	72	36.00
	50 days	8	4.00
Manure	No-adoption at all	23	11.50
	Below recommended dose	139	69.50
	As per recommended dose (10 ton/ha)	38	19.00
	More than recommended dose	0	0.00
Fertilizer	**N**		0.00
	No-adoption at all	51	25.50
	Less quantity than recommended dose (kg)	100	50.00
	As per recommended does (kg)	14	07.00
	More quantity than recommended does	35	17.50
	P		0.00
	No-adoption at all	0	0.00
	Less quantity than recommended dose (kg)	98	0.00
	As per recommended does (kg)	68	0.00
	More quantity than recommended does	34	0.00
Plant protection Measures	Not adopted at all	200	100.00
Storage	Storage bin	62	31.00
	Deshi Kothi	91	45.50
	Gunni bags	47	23.50

to 20000 while 26.00 percent having less than Rs.10000 income. 12.00 percent having the income between Rs.20000 to 30000 while no one having Income above Rs.50000.

Knowledge about scientific maize production technology

Improved variety: More than 50 per cent farmers adopting improved variety of maize for cultivation while 28.50 percent adopting local deshi varieties. About 17.50 percent farmers adopting private varieties.

Seed rate: About 50 per cent farmers were adopting seed rate as per scientific recommendation.While more than 40 percent farmers were adopting seed rate more than recommendation.

Seed treatment: 65 percent farmers were using readymade treated seed.While 35 per cent farmers were treated the seed in correct way by own and used for sowing.

Use of culture: 65 percent farmers were not adopting the culture while 35per cent using in proper way.

System of sowing: 98.50 per cent farmers were adopting as per recommendation *i.e.* dibbling method while 1.50 per cent adopting drilling method.

Time of sowing: 100 percent farmers were adopting the sowing time as per recommendation.

Row spacing: 43.50 per cent farmers were adopting row spacing as per recommendation while others were adopting their own method.

Thinning: More than 86.00 per cent of farmers were adopting thinning (15 to 25 DAS). 13.50 per cent were not adopting as per recommendation.

Earthing up: More than 96% of farmers were adopting earthingup (30 to 40 DAS) and 4% not.

Manure: Only 19.00 per cent adopting as per recommendation while 69.50 per cent adopting below recommendation. 4.00 per cent were not adopting at all.

Chemical fertilizer:

Nitrogen: 50.00 percent were adopting the dose of below recommendations while 17.50 percent were adopting more than recommendation. 25.50 percent were not adopting at all.

Phosphorus: 49.00 percent were adopting the dose of phosphorus below recommendation. 34.00 percent were adopting as per recommendation while 17.00 percent were adopting more than recommended dose.

Plant protection measures: 100.00 percent of farmers were not adopting at all.

Storage: 45.50 percent were stored maize grain in DeshiKothi, 31.00 percent were stored maize gratin in storage bin while 23.50 percent using gunnibags for storage of maize grain.

From the above discussion, it could be concluded that majority of the respondents was in middle age group, were illiterate, were less participate in social activities, had annual income is Rs.10001 to 20000 were engaged in farming + Animal husbandry as main occupation, possessed less than 2.00 ha land were found to have medium level of knowledge about scientific maize production technology and were medium adopters of the maize production technology.

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Effect of graded fertility levels on performance of quality protein maize (*Zea mays* L.) varieties

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ABSTRACT

A field experiment was conducted during *kharif* 2014 to evaluate production performance of quality protein maize (QPM) hybrids at varying fertility levels. The treatment consisted combinations of four QPM varieties ("HQPM-1", "HQPM-5", "Pratap QPM hybrid-1" and "Vivek QPM-9") and four fertility levels (90 + 30, 110 + 40, 130 + 50 and 150 + 60 kg N +P_2O_5 ha^{-1}). With highest values of yield attributing parameters, consequently grain (42.62 q ha^{-1}), stover yield (63.34 kg ha^{-1}), net return (45176 Rs. ha^{-1} and B C ratio (2.42), the QPM variety "HQPM-1" proved economically profitable. Total uptakes of N, P and K by plants of "HQPM-1" were significantly higher over rest of the varieties. Protein content of "HQPM-1", "HQPM-5" and "Pratap QPM-1" were statistically at par but significantly higher over "Vivek QPM-9". At harvest, soil with experimental plots of "Vivek QPM-9" retained significantly higher N and P_2O_5, however, K status of soil did not vary significantly. For QPM, application of 150 kg N + 60 kg P_2O_5ha^{-1} significantly improved growth, yield attributing parameters, grain and stover yield and proved economically profitable dose. Total uptake of nutrients by plants and soil status of N and P_2O_5 after harvest of crop were higher under application of 150 kg N + 60 kg P_2O_5ha^{-1}, however, K status of soil did not differ significantly with varying fertility levels.

Keywords: Fertility levels and QPM varieties

Maize is an important cereal crop of India and is grown on 8.67 m ha with the production and productivity of 21.75 m t and 2566 kg ha^{-1} , respectively (Govt. of India, 2014). Out of total production 45 per cent is consumed as staple food in various forms. Besides this maize is a main ration for poultry birds. Forage maize is used as fresh or dry fodder. In recent past, high yielding single cross hybrids of quality protein maize were developed by addition of opaque-2 mutant gene, which improved lysine and tryptophan and reduced leucine and isoleucine contents and produce quality protein with balanced composition of amino acids (Parsana *et al*., 2011). The most important goal of enhancing productivity of QPM is to reduce malnutrition through direct human consumption in tribal dominated areas, where maize is staple food (Sofi *et al.*, 2009). The QPM varieties have slow growth initially but vigorous growth afterwards, thus, its N and P requirement is high compared to other hybrids (Singh, 2010). In QPM, nitrogen stress during flowering stage results in kernel and ear abortion and stress during grain filling accelerates leaf senescence reduce photosynthesis and kernel weight (Zaidi *et al*., 2005). Our most of the soils are having medium to low status of nitrogen and phosphorus, hence, adequate nitrogen and phosphorus is considered to be one of the most important pre-requisites for increasing grain and stover yield of quality protein maize. Considering these facts and paucity of research findings, the trial was conducted to select best variety of QPM and to find out suitable N and P dose under agro climatic condition of sub-humid southern and Arawali hills of Rajasthan.

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MATERIALS AND METHODS

A field experiment was carried out during kharif 2014 at the instructional Farm, Rajasthan College of Agriculture, Udaipur, and Rajasthan. The soil of the experimental site was clay loam having pH 7.8, organic carbon 0.81, available nitrogen 295.8 kg ha^{-1}, available phosphorus 18.8 kg ha^{-1} and available potassium 309.6 kg ha^{-1} in the plough layer. The well distributed rainfall of 578 mm was recorded during crop growth period. The treatment consisted combinations of four quality protein maize varieties ("HQPM-1", "HQPM-5", "Pratap QPM hybrid-1" and "Vivek QPM-9") and four fertility fertilizer levels (90 +

30, 110 + 40, 130 + 40, 150 + 60 kg N +P_2O_5 ha^{-1}) and were evaluated four times in factorial randomized block design. The crop was sown manually on 10th July, 2014 by placing two seeds at a depth of 4-5 cm at 60 x 25 cm. The experimental plot size was 5 x 3 m. Thinning was carried out at 15 days after sowing to maintain required plant population.

Phosphorus as per treatments was applied as basal, whereas nitrogen was applied in three equal splits *viz.*, 1/3 as basal, 1/3 at knee high stage and remaining 1/3 at initiation of tassel. In order to minimize weed competition, pre-emergence application of atrazine at 0.5 kg ha^{-1} followed by one hoeing and earthing up at 20 days after sowing was carried out. Net returns and B C ratio were calculated on basis of prevailing market prices of inputs and produce. Leaf area index (LAI), chlorophyll, protein content, nutrient content and uptake, crop growth rate (CGR) and relative growth rate (RGR) were worked out by using standard methods for analysis and formula. Data of each character collected were statistically analyzed using standard procedure of variance analysis.

RESULTS AND DISCUSSION

Fertility levels

Growth, yield attributes and yield:

Application of 150 kg N + 60 P_2O_5/ha significantly enhanced growth and yield attributing parameters QPM varieties over 130 kg N + 60 P_2O_5 ha^{-1}. Days to 50 per cent silking and plant population did not vary significantly under different fertility levels. The significant response up to 150 kg N + 60 kg P_2O_5 ha^{-1} might be on account of enrichment of soil with two major nutrients N and P to the level of sufficiency which in turn promoted growth of plant right from early stage (Suthar *et al.* 2013 and Choudhray *et al.* 2013).

Nutrient uptake and protein content

The maximum nutrient content and total uptake of N, P and K and protein content of grain by QPM plants were registered under 150 kg N + 60 kg P_2O_5 ha^{-1} which were significantly higher over rest of the varieties. The significant increase in N, P and K content and uptake of plant parts at harvest seems to be on account of capabilities of QPM plants for efficient absorption, translocation and utilization of mineral nutrients (Singh, 2010 and Choudhary *et al.*, 2013). The improvement in protein under the influence of 150 kg N + 60 kg P_2O_5 ha^{-1} seems to be on account of increased N content of grain. It is well known fact that N is a constituent of protein, enzymes and chlorophyll and participates in several biochemical processes for the metabolism of carbohydrate, fat and protein in plant system (Nath *et al.* 2009).

Soil nutrient status

Application of 150 kg N + 60 kg P_2O_5 ha^{-1} retained significantly higher N and P_2O_5. The results are quite self-explanatory in light of the fact that the increase in available nitrogen and phosphorus status of soil under application of 150 kg N + 60 kg P_2O_5 ha^{-1} could be ascribed that added nutrients are used for growth and sustaining higher yield on one hand, and assured restoration of soil fertility on other (Totawat *et al.*, 2010).

Varieties

Growth, yield attributes and yield:

Plant population did not differ significantly amongst different varieties (Table 1). Highest CGR was recorded under "HQPM-1" which was at par with "Pratap hybrid QPM-1' and both of these proved significantly higher over rest of the varieties. The crop of "HQPM-1" attained the highest plant height, dry matter, LAI, grain weight $plant^{-1}$, cob length and shelling per cent which were significantly higher over rest of the varieties. Consequently highest grain (42.6 q ha^{-1}) and stover (63.3 q ha^{-1}) yield were recorded under HQPM-1 which was significantly higher over rest of the varieties. With highest net returns (45176 ha^{-1}) and B C ratio (2.42) the "HQPM-1" proves economically profitable variety. The next nest variety is "HQPM-5" and "Pratap QPM hybrid-1". Under present investigation, the better performance of "HQPM-1" seems to be on account of higher uptake of nitrogen and phosphorus (Table 2) from soil and its reallocation in grain and plant. The higher availability of nitrogen and phosphorus seems to have promoted development of morphological structure by virtue of multiplication of cell division which is well reflected through increased leaf area index, crop growth rate and relative growth rate (Choudary *et al.*, 2013). The post flowering stalk rot affected plants was highest in "Vivek QPM-9" which was significantly higher over rest of the varieties. This proves that variety is highly susceptible to post flowering stalk rot in the maize growing region of Rajasthan.

Nutrient uptake and protein content

The highest N, P and K content and uptake, protein in grain and stover were recorded under "HQPM-1" and "HQPM-5" compared to rest of the varieties. The least uptake and protein were recorded in "Vivek QPM-9". There was adequate supply of metabolites from shoot to roots which might have facilitated better root growth thus higher extraction of nutrients from soil environment (Suthar

Table 1. Effect of varieties and fertility levels on growth and yield attributing parameters

Treatments	Plantsat harvest (000ha^{-1})	Plant height at harvest (cm)	Days to 50% silking	DM at harvest $plant^{-1}$ (g)	LAI at 60 DAS	CGR 30-60 DAS	Grain wt. $plant^{-1}$	Coblength (cm)	Test weight (g)	Shelling (%)	PFSR Affected plants ha^{-1}	Yield (q ha^{-1}) Grain	Stover
Fertility levels (kg ha^{-1})													
90 kg N + 30 kg P_2O_5	64.60	196.2	51.9	114.6	2.55	10.01	44.3	15.1	167.8	68.5	15.70	29.4	43.0
110 kg N + 40 kg P_2O_5	64.44	204.7	52.0	131.5	2.66	11.25	51.4	16.1	180.8	72.6	15.87	34.5	50.0
130 kg N + 50 kg P_2O_5	63.95	208.9	51.8	146.9	2.73	12.27	58.9	16.5	187.9	74.0	16.06	38.8	57.0
150 kg N + 60 kg P_2O_5	64.30	211.2	51.5	160.7	2.79	12.93	65.0	17.1	190.7	76.5	16.26	41.7	62.5
SEm±	0.18	0.74	0.19	0.79	0.01	0.06	0.34	0.08	0.85	0.27	0.05	0.21	0.27
CD (P = 0.05)	NS	2.10	NS	2.25	0.04	0.17	0.96	0.23	2.43	0.76	0.15	0.60	0.78
Varieties													
Pratap QPM hybrid-1	64.11	206.9	50.5	151.2	2.69	12.27	58.4	16.2	194.8	70.5	0.25	38.7	56.3
Vivek QPM-9	64.65	205.4	50.3	89.4	2.68	11.06	35.2	15.2	137.3	67.0	63.09	24.1	34.5
HQPM-1	64.30	208.3	53.4	163.4	2.73	13.07	66.9	17.3	199.9	77.0	0.27	42.6	63.3
HQPM-5	64.23	200.5	53.0	149.8	2.64	10.06	59.0	16.2	195.2	77.0	0.28	39.0	58.5
SEm±	0.18	0.74	0.19	0.79	0.01	0.06	0.34	0.08	0.85	0.27	0.05	0.21	0.27
CD (P = 0.05)	NS	2.10	0.53	2.25	0.04	0.17	0.96	0.23	2.43	0.76	0.15	0.60	0.78

DM: Dry matter, **LAI:** Leaf area index, **CGR:** Crop growth rate, **RGR:** relative growth rate and **PFSR:** Post flowering affected plants

Table 2. Graded fertility levels on yield, nutrient content and uptake, protein content of QPM varieties, soil nutrient status and economics.

Treatments	Nutrient content (%)						Total nutrient uptake by plant (kg ha^{-1})			Protein content (%)	Nutrient status of soil (kg ha^{-1})			Net returns (Rs. ha^{-1})	B C ratio
	Grain			Stover											
	N	P	K	N	P	K	N	P	K	Grain	N	P_2O_5	K_2O		
Fertility levels (kg ha^{-1})															
90 kg N + 30 kg P_2O_5	1.525	0.322	0.414	0.635	0.155	1.122	72.8	16.2	60.5	9.53	266.8	17.40	291.9	25996	1.45
110 kg N + 40 kg P_2O_5	1.712	0.335	0.415	0.665	0.165	1.122	93.2	19.9	70.4	10.70	272.6	17.81	293.4	33036	1.79
130 kg N + 50 kg P_2O_5	1.738	0.345	0.415	0.702	0.172	1.122	108.3	23.3	80.1	10.86	277.4	18.45	293.3	39137	2.08
150 kg N + 60 kg P_2O_5	1.748	0.347	0.415	0.722	0.176	1.124	119.2	25.5	87.7	10.93	284.0	18.99	294.3	43302	2.25
SEm±	0.003	0.001	0.003	0.002	0.0003	0.001	0.53	0.15	0.40	0.02	0.48	0.03	0.68	298	0.02
CD (P = 0.05)	0.008	0.003	NS	0.005	0.0010	NS	1.52	0.43	1.14	0.05	1.35	0.08	NS	849	0.05
Varieties															
Pratap QPM hybrid-1	1.730	0.338	0.414	0.678	0.167	1.123	106.0	22.6	79.3	10.81	274.6	17.88	293.1	39117	2.09
Vivek QPM-9	1.531	0.328	0.414	0.653	0.164	1.122	59.9	13.8	48.7	9.57	280.9	18.89	292.4	17246	0.92
HQPM-1	1.728	0.341	0.415	0.685	0.168	1.122	117.8	25.3	88.7	10.80	272.4	18.01	293.0	45176	2.42
HQPM-5	1.734	0.342	0.415	0.707	0.168	1.124	109.8	23.4	82.1	10.84	273.0	17.88	294.4	39933	2.14
SEm±	0.003	0.001	0.003	0.002	0.0003	0.001	0.53	0.15	0.40	0.02	0.48	0.03	0.68	298	0.02
CD (P = 0.05)	0.008	0.003	NS	0.005	0.0010	NS	1.52	0.43	1.14	0.05	1.35	0.08	NS	849	0.05

et al. 2013). The poor performance of "Vivek QPM-9" in terms of N and P uptake could be ascribed on account of mortality of plant by infection of post flowering stalk rot around silking to grain formation stage which restricted plant to exploit available resources for their growth and development.

Soil nutrient status

N and P_2O_5 status of soil after harvest of crop was significantly higher in plots with variety "Vivek QPM-9". Enhanced availability of N and P status of experimental plots with "Vivek QPM-9" might be on account higher infestations of post flowering stalk rot around silking to grain formation stage which restricted genetic capabilities of plant to exploit available N and P from soil for their growth and development thus increase available N and P status of soil under "Vivek QPM-9" is expected.

On the basis of results emanated from the present experiment conducted during *kharif* 2014, it is concluded that under prevailing agro climatic conditions, 150 kg N + 60 kg P_2O_5 ha^{-1} proved most efficient and economically profitable for quality protein maize hybrid "HQPM-1". Though this interaction effect was not significant, however, fetched highest net returns of ` 53045 ha^{-1} and benefit cost ratio of 2.75.

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Growth and yield of maize (*Zay mays*) as influenced by various weed management practices

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ABSTRACT

A field experiment was conducted to study the integrated weed management in maize *(Zea mays* L.) for consecutive two *kharif* seasons in 2012 and 2013 at Zonal Agriculture Research Station, Jhabua with combination of 8 weed management treatments. The experiment was laid out in Randomized Block Design (RBD) with three replications. The Maize hybrid Bio -9637 was sown during both the years of course of investigations with row to row spacing 60 cm and plant to plant spacing 25 cm. The crop was given recommended amount of nutrients i.e. 120 kg N/ha, 60 kg P_2O_5/ha and 40 kg. Data relating to weed density were recorded from a randomly selected area measuring 50 x 50 cm from each plot and then converted to count per square meter. Weeds after taking the weed count data were dried together plot wise and the data converted to dry matter of weeds in gm per sq meter. Hand weeding at 20 & 40 DAS was found most effective to control weeds. The density of grassy weeds (5.57 and 6.63), Broad leaf weeds (9.43 and 8.87) as well as total weeds (15 & 15.5) in 2012 & 2013 respectively, were found significantly lowest in Two hand weeding at 20 & 40 DAS and it was found at par with. Atrazine 1.0 kg a.i./ ha as Pre Emergence. Likewise significantly lowest dry matter of weeds at 50 DAS were found in Two hand weeding at 20 & 40 DAS and it was found at par with Atrazine 1.0 kg a.i./ha as PE. Highest yield (43.31& 50.21 qt/ha) was also observed in Two hand weeding at 20 & 40 DAS closely followed by Atrazine 1.0 kg a.i./ha as Pre Emergence (41.69 & 47.04 qt/ha) during 2012 and 2013 respectively. However, on the basis of B:C ratio, Atrazine 1.0 kg a.i./ha as pre-emergence gave the highest B:C ratio followed by two hand weeding at 20 & 40 DAS and found most economical weed management practices

Keywords: Growth and yield, maize

Maize *(Zea mays* L.) is one of the most versatile crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as "Queen" of cereals because of its highest yield potential among cereals. Being a C4 plant, maize is capable of utilizing solar radiation more efficiently compared to other cereals. In India, the maize is third important cereal crop after rice and wheat and is cultivated in an area of 8.67 mha with a production of 22.26 mt and productivity of 2566 kg/ha. In Madhya Pradesh, maize is grown on 0.85 mh area with the productivity of only 1790 kg/ha which is very low as compared to national average (Annonymous, 2014). Parihar and Jat (2011) gave that maize is used in diversified ways i.e. for human consumption (23%), as poultry feed (51%), as animal feed (12%), industrial (starch) products (12%), beverages and seed (1% each).

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Factors that limits productivity is sever weed competition. Weeds pose a serious threat to the cultivation of *kharif* maize. Slow initial growth, wider row spacing, high humidity and adequate soil moisture during rainy season provide adequate conditions for luxuriant growth of weeds. Maize crop infested with a wide variety of weeds causes yield losses ranging from 34 to 67 per cent and sometimes even more (Sharma *et al.*, 2000; Sreenivas and Satyanarayana, 1994). Hence, timely removal of weeds using a suitable weed control method is very much crucial to obtain the optimum yield of maize during *kharif* season. Hand weeding is laborious, time consuming, costly and tedious job. Furthermore, timely unavailability of labour as well as continuous rain do not permit timely hand weeding. Integrated weed management includes the combination of cropping practices for efficient and economical weed control (Swanton and Weise, 1996). The wider row spacing in maize can be used to grow short duration legumes which not only act as smoother crop, but also give additional yield (Shah *et al.*, 2011). Therefore, an attempt has been made to study the integration of weed management practices to get the best weed management option and highest yield of maize.

MATERIALS AND METHODS

A field experiment was conducted during two consecutive *kharif* seasons of 2012 and 2013 at Zonal Agricultural Research Station Farm, Jhabua (M.P.). The soil of experimental field was loamy sand in texture, normal in soil reaction (pH 7.4), low in available nitrogen (215 kg/ha), medium in available phosphorus (12.8 kg/ha) and potassium (270 kg/ha). A total of 939.4 cm (38 rainy days) and 1215.4 cm (52 rainy days) rainfall was received during the crop growing season in 2012 and 2013, respectively. The experiment was laid out in Randomized Block Design (RBD) with three replications and eight treatments. Treatment consisted of Atrazine 1.0 kg a.i./ha as PE (T_1), Atrazine 1.0 kg a.i./ha at 15-20 DAS (T_2), Pendamethilen 1.0 kg a.i./ha as PE (T_3), Organic mulh 6 t/ha (T_4), Maize + cover crop (cowpea) (T_5), One hand weeding at 20 DAS (T_6), Two hand weeding at 20 & 40 DAS (T_7) and Unweeded check (T_8). These herbicides were sprayed using 375 l/ha with knapsack sprayer fitted with a flat fan nozzle. In the case of two hand weeding, weeds were removed manually at 20 and 40 DAS. In case of unweeded check plots weeds are allowed during the whole crop growing season. Data relating to weed density were recorded from a randomly selected area measuring 50 x 50 cm from each plot and then converted to count per square meter. Weeds after taking the weed count data were dried together plot wise and the data converted to dry matter of weeds in gm per sq meter.

The Maize hybrid Bio -9637 was sown in 1st week July in 1st year and in 4th week of June in second year of course of investigations, with row to row spacing 60 cm and plant to plant spacing 25 cm. The crop was given recommended amount of nutrients i.e. 120 kg N/ha, 60 kg P_2O_5/ha and 40 kg. One third of nitrogen and full dose s of P_2O_5 and K_2O was applied as basal dose and remaining two-third of nitrogen was applied in two equal splits at Knee-High and pre teaseling stage. Observations on vegetative and yield characters were recorded during course of investigation. Data recorded on each character were analyzed.

RESULTS AND DISCUSSION

Weed flora

The major weed flora was Commelina benghalensis, Digera arvensis, Celosia argentia, Euphorbia hirta, Echinocloa colonum, Echinocloa crusgalli, Cyprus rotundus, Amaranthus viridis, Portulaca oleracea, Achyranthus aspera, Xanthomonas strumarium, Trianthema portulacastrum, Cynodon dactylon.

Effect on weed

All the weed management practices caused significant reduction in monocot and dicot weeds and their dry weight recorded at 50 DAS. Significant lower density of monocot and dicot weeds were recorded in twice hand weeding done at 20 and 40 DAS during both the year. However, it was found statistically at par with Atrazine 1.0 kg a.i./ha PE. Hand weeding carried out at 20 & 40 DAS recorded significantly lower density of monocot, dicot and total weeds as compared to One hand weeding at 20 DAS, Atrazine 1.0 kg a.i./ha at 15-20 DAS, Pendimethalin 1.0 kg a.i./ha as PE, Organic mulch @ 6 t/ha, Maize + Cover crop (Cow pea) and Weedy Check. After Hand weeding at 20 & 40 DAS, lowest weed density was observed in Atrazine 1.0 kg a.i./ha PE followed by Pendimethalin 1.0

Table 1. Effect of different treatments on weed density (no./m^2) at 50 DAS

Treatment	Monocot weeds (no./m^2)		Dicot weeds (no./m^2)		Total weeds (no./m^2)	
	2012	2013	2012	2013	2012	2013
Atrazine 1.0 kg a.i./ha PE	12.90	9.47	11.90	11.27	24.80	20.73
Atrazine 1.0 kg a.i./ha at 15-20 DAS	31.77	34.10	37.23	35.77	69.00	69.87
Pendimethalin 1.0 kg a.i./ha as PE	21.43	24.07	28.43	31.10	49.87	55.17
Organic mulch @ 6t/ha	28.43	31.60	36.23	28.13	64.67	59.73
Maize + Cover crop (Cowpea)	32.77	37.70	62.73	42.83	95.50	80.53
One hand weeding at 20 DAS	20.57	23.93	26.23	26.57	46.80	50.50
Two hand weeding at 20 & 40 DAS	5.57	6.63	9.43	8.87	15.00	15.50
Weedy Check	66.10	56.10	93.77	70.00	159.87	126.10
LSD (P=0.05)	7.20	7.60	8.08	6.43	12.33	7.75

kg a.i./ha as PE and Organic mulch @ 6 t/ha. Atrazine 1.0 kg a.i./ha at 15-20 DAS and Maize + Cover crop (Cowpea) have least impact on weed density reduction as compared to other treatments. Further, it was observed that significantly lower dry weight of monocot and dicot weeds were recorded under hand weeding at 20 & 40 DAS, which was at par with Atrazine 1.0 kg a.i./ha PE. The trend in reduction of dry matter of weeds was found similar to weed density during both the years. Kandasamy and Chandrasekhar (1998); Gaur and Kaushik (1991) also expressed similar opinions. Among herbicides, Atrazine 1.0 kg a.i./ha as Pre-emergence has lowest dry matter of monocot as well as dicot weeds followed by Atrazine 1.0 kg a.i./ha at 15-20 DAS and Pendimethalin 1.0 kg a.i./ha as PE.

Effect on growth and yield

Weed control treatments significantly influenced plant height and yield of maize. In general plant height and yield were superior in the case of two hand weedings carried out at 20 & 40 DAS. Maximum plant height was observed under two hand weeding at 20 & 40 DAS closely followed by Atrazine 1.0 kg a.i./ha as pre-emergence and found at par with two handing. One hand weeding at 20 DAS, Atrazine 1.0 kg a.i./ha at 15-20 DAS, Pendimethalin 1.0 kg a.i./ha as PE and Organic mulch @ 6 t/ha have also increase the plant height significantly as compared to weedy check during both the years.

Similar trends were observed in yield also and maximum yield observed under hand weeding at 20 & 40 DAS and it was found closely at par with Atrazine 1.0 kg a.i./ha as pre-emergence. Rest of the treatments were also found significant superior over weedy check during both the year. Shelling percentage was not significantly influenced by any weed management practices during 2012. However, highest shelling percentage was observed under Two hand weeding at 20 & 40 DAS and Atrazine 1.0 kg a.i./ha as pre-emergence during 2012. During 2013, significantly higher shelling percentage was observed in Two hand weeding at 20 & 40 DAS and Atrazine 1.0 kg a.i./ha as pre-emergence and rest of the treatment found at par with weedy check.

Table 2. Effect of different treatments on weed dry matter (g/m^2) at 50 DAS

Treatment	Monocot weeds (g/m^2)		Dicot weeds (g/m^2)		Total weeds (g/m^2)	
	2012	2013	2012	2013	2012	2013
Atrazine 1.0 kg a.i./ha PE	3.68	5.20	3.08	6.70	6.76	11.90
Atrazine 1.0 kg a.i./ha at 15-20 DAS	5.78	12.07	6.67	13.47	12.44	25.53
Pendimethalin 1.0 kg a.i./ha as PE	4.40	9.07	7.24	12.37	11.65	21.43
Organic mulch @ 6 t/ha	5.21	11.23	9.09	11.70	14.30	22.93
Maize + Cover crop (Cow pea)	6.03	15.10	10.36	14.50	16.39	29.60
One hand weeding at 20 DAS	4.05	8.10	6.63	9.97	10.67	18.07
Two hand weeding at 20 & 40 DAS	3.13	4.30	3.39	5.90	6.51	10.20
Weedy Check	7.89	17.10	12.57	16.83	20.46	33.93
LSD (P=0.05)	1.08	2.12	1.88	2.28	2.37	3.45

Table 3. Effect of different treatments on plant height, grain yield, shelling % & B:C ratio

Treatment	Plant height (cm)		Grain yield (kg/ha)		Shelling %		B:C ratio	
	2012	2013	2012	2013	2012	2013	2012	2013
Atrazine 1.0 kg a.i./ha PE	180.0	186.8	4169	4704	82.50	82.78	2.12	2.07
Atrazine 1.0 kg a.i./ha at 15-20 DAS	165.7	173.4	3111	3429	81.08	79.82	1.78	1.72
Pendimethalin 1.0 kg a.i./ha as PE	174.1	180.3	3495	3987	82.49	81.75	1.83	1.79
Organic mulch @ 6 t/ha	168.1	175.7	3190	3614	80.80	80.20	1.65	1.61
Maize + Cover crop (Cowpea)	164.0	170.3	3069	3354	81.67	80.34	1.58	1.49
One hand weeding at 20 DAS	177.0	182.3	3651	4217	81.92	81.82	1.76	1.74
Two hand weeding at 20 & 40 DAS	182.4	188.8	4331	5021	82.63	83.74	1.94	1.88
Weedy Check	158.5	155.7	2601	2831	81.83	79.25	1.34	1.27
LSD (P=0.05)	7.86	8.64	354	250	2.55	2.17		

Economics

Economics of different weed control treatments showed that Atrazine 1.0 kg a.i./ha as pre-emergence gave the highest B:C ratio followed by two hand weeding at 20 & 40 DAS. Although maximum yield obtained under two hand weeding treatment but on the basis of economics Atrazine 1.0 kg a.i./ha as PE found most economical weed management practices. Pandey *et al*. (2001) also concluded that the chemical control of weeds is more economical than hand weeding.

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Effect of vesicular arbuscular mycorrhiza on maize growth and yield

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ABSTRACT

A field experiment was conducted to study the effect of Vesicular Arbuscular Mycorrhiza (VAM) on maize growth and yield during *kharif, 2012*. Leaf area index, chlorophyll index, leaf area of flag leaf and stem girth of maize were significantly higher with VAM top dressing + RDF and was at par with VAM seed treatment + RDF. Grain weight/cob was also significantly higher in when crop received with VAM top dressing + RDF and was on par with maize received with VAM top dressing + 75% RDF, VAM seed treatment + RDF and maize with only RDF only. The unfilled tip portion of cob was significantly lowest in maize received with VAM top dressing + RDF and was on par with all VAM top dressing treatments at any fertilization. The cob and grain yield of maize (DHM 117) was significantly higher with application of VAM top dressing + RDF and was on par with VAM seed treatment + RDF, VAM top dressing + 75% RDF & RDF control plot. In conclusion, the application of VAM top dressing + RDF, followed by VAM seed treatment + RDF, VAM top dressing + 75% RDF can be a suitable option without any reduction in yield significantly and statistically for getting higher benefit to cost ratio as well.

Keywords: Growth attributes, Maize, VAM, Yield and yield

Maize is considered as a promising option for diversifying agriculture in upland areas of India. It now ranks as the third most important food grain crop in India. The maize area has slowly expanded over the past few years. Paroda and Kumar (2000) predicted that this area would grow further to meet future food, feed and other demands especially in view of the booming livestock and poultry producing sectors in the country. The demand for increased production will not be met just by the expansion in cultivated area, but more by intensifying production. The continuous and intensive cropping system steadily declines the nutrient supplying capacity of soil. Intensification will therefore need nutrient management that produces high yield same time sustains the soil and environment. The optimum levels of NPK failed to maintained yield levels probably due to increasing secondary and micro nutrient deficiencies and also unfavorable alterations in the physical and chemical properties of the soils. Apart from the soil fertility and productivity issues, use of chemical fertilizers is also becoming more and more difficult for the farmers due to their high costs and scarcity during peak season. On this, increasing awareness is being created on the use of organics including bio-fertilizers which are the source of macro, micro and secondary nutrients to sustain the soil fertility and productivity.

In an attempt, to reduce environmental risk and cost of chemical fertilizer, use of bio-fertilizers such as mycorrhizal fungi has been considered as possible substitutes for traditional mineral P fertilizer availability. Mycorrhiza is a symbiosis between most crops and certain fungi which exists in most of the ecosystems. Vesicular arbuscular mycorrhizas (VAM) are widespread in field crops and many investigations have demonstrated that plant growth may be increased by them (Jeffries, 1987). In short season crops a significant effect of VAM on plant growth must depend on early infection (Tinker, 1975), this in turn is related to inoculums density, which can be increased either through inoculation or through judicial manipulation of agronomic practices (Sieverding, 1986). Mycorrhiza cause more efficient P uptake, decrease risk of soil erosion, reduces the phosphorus leaching, increases photosynthesis and water use efficiency and also resistance to biotic and non biotic stresses (Cardiso *et al*.,2006; Dodd, 2000).

Although, there is great potential in the use of mycorrhiza, research in this field, especially in developing countries, still remains poor. Hence the present investigation was undertaken to study the effect of vesicular arbuscular mycorrhiza (VAM) on maize growth, yield attributes and yields.

MATERIALS AND METHODS

The field study was conducted during *kharif* 2012-13 cropping season at Agricultural Research Station, Karimnagar situated at 79° 15 east longitude, 18° 30 north latitude with an elevation of 259.15 m above mean sea level. It comes under Northern Telangana Agro climatic zone of Telangana state which falls under semi arid climate with dry hot summer and cool winter. The actual rainfall received during *kharif* 2012 from June to October 2012 is 721.2 mm in 51 rainy days. The study site is characterized with red sandy loam soils in texture, neutral in reaction, with electrical conductivity of 0.29 ds/m (Non-saline), organic carbon 0.65 (Medium), available nitrogen as 229.4 kg/ha (Medium), available P_2O_5 is 32.84 kg/ha (Medium) and available K_2O is 263 kg/ha (Medium).

The experiment was laid out in RBD design, replicated thrice with 7 treatments as T1 –Vesicular Arbuscular Mycorrhiza (VAM) seed treatment + Recommended dose of fertilizer (RDF); T2 – VAM seed treatment + 75% RDF; T3 – VAM seed treatment + 50% RDF; T4 – VAM topdressing + RDF; T5 – VAM topdressing + 75% RDF; T6 – VAM topdressing + 50% RDF; T7 – Control (RDF). Seed treatment of VAM was carried out @ 80 ml of VAM per 1 kg seed and topdressing of VAM was done at 30 DAS @ one liter of VAM mixed with 100 kg of vermin-compost and covered with soil. This top dressing was not coincided with the topdressing of urea and there was a gap of 4 days between both the topdressing. The popular maize hybrid, DHM 117 was sown on 26th June 2012 during *kharif* season and harvested on 16th October 2012. Uniform cultural operations and plant protection measures were adopted in all treatments. The spacing of 75x20 cm and fertilizer dose of 200-60-50 kg NPK/ha was applied as recommended dose with entire P as basal, Nitrogen in four equal splits and K as basal (50%) and at flowering (50%). Accordingly the fertilizer dose for 75 and 50 % RDF was calculated and applied. The observations on growth, yield attributes and yield were recorded. The growth parameter, leaf number/plant was recorded in 10 labeled plants at 60 DAS. The area of flag leaf and also all the leaves was also recorded in the same labeled plant, dry matter production at 60 DAS was calculated by taking 2 plants /treatment and oven drying. The Leaf Area Index was calculated by dividing the total leaf area of plant with the covered land area by the plant. The chlorophyll index readings were taken by the digital chlorophyll meter at 60 DAS. Post harvest yield attributes and yield as per treatment were recorded and calculated on per hectare basis. The economic returns were compared by calculating B:C ratio for different VAM treatments.

RESULTS AND DISCUSSION

Effect of VAM on flowering of maize

The data on initial flowering, days to 50% tasseling and silking among different treatments of vesicular arbuscular mycorriza (VAM) on maize crop was depicted in Table 1. Initial flowering /day to 50% tasseling & silking showed that the flowering was delayed in maize crop receiving less fertilization i.e. 75 & 50% record dose than compared the crop applied with recommended dose of fertilizer (Table 1).

Effect of VAM on growth parameters of maize

The growth parameters i.e. plant height, ear height at harvest, leaf number/plant at 60 DAS and dry mater g/m^2 at 60 DAS did not differ significantly with different VAM treatments under test. While, the growth parameters i.e., mean leaf area of flag leaf, chlorophyll index, mean stem girth at 7th node at harvest and leaf area index at 60 DAS differed significantly with different VAM treatments under test.

The comparison between different treatments indicated that the plant and ear height recorded higher with maize crop receiving VAM top dressing with recommended dose of fertilizer (RDF) followed by VAM seed treatment + RDF (Table 2). While, the mean leaf number /plant at 60 DAS was same in both the maize crop applied with recommended dose of fertilizer & VAM either as top dressing /seed treatment (15.7). The dry matter /m^2 also followed the similar trend and resulted in higher dry matter in maize with VAM top dressing + RDF (1294 g/m^2) followed by maize with VAM seed treatment

Table 1. Effect of VAM on flowering of maize (DHM 117) crop

Treatment No.	Initial flowering (DAS)	Days to 50% tasseling (DAS)	Days to 50% silking (DAS)
T1: VAM seed treatment + RDF	45	48	51
T2: VAM seed treatment + 75% RDF	46	49	51
T3: VAM seed treatment + 50% RDF	47	50	52
T4: VAM Topdressing + RDF	45	48	50
T5: VAM Topdressing + 75% RDF	45	49	51
T6: VAM Topdressing + 50% RDF	46	50	53
T7: Control (RDF)	46	49	52

+ RDF (1274 g/m^2) agreeing with Etukudo *et al*. (2015), finalizing that the number of leaves did not increase significantly under 8 WAP. This study also recorded effect of VAM on no. of leaves/plant non-significantly.

The mean leaf area of flag leaf at 60 DAS differed significantly with different VAM treatment under test. It was noticed that maize crop receiving VAM top dressing + RDF has recorded significantly higher flag leaf area (859.7 cm^2), and was found to be on par with maize receiving VAM as seed treatment + RDF (833.7 cm^2), maize receiving only RDF (822.7 cm^2), VAM as top dressing + 75% RDF (805.7 cm^2), VAM as seed treatment + 75% RDF (779 cm^2). Significantly the lowest flag leaf area was recorded with maize crop receiving 50% RDF and VAM seed treatment (640 cm^2) and maize with 50% RDF + VAM top dressing (672.7 cm^2) which were found to be on par with each other. This was confirmed by Etukudo *et al.* (2015) who have also reported leaf area increase in mycorrhiza inoculated maize plants than compared to non inoculated plate at 4, 6 and 8 WAP.

The chlorophyll index at 60 DAS was significantly influenced by different VAM treatments (Table 2). It was noticed that significantly higher chlorophyll index was recorded in maize crop with VAM top dressing + RDF (46.8%) and was on par with maize with VAM seed treatment + RDF (44.8%), maize with RDF (Control) only (44.8%), maize with VAM top dressing + 75% RDF (43.5%), maize with VAM top dressing + 50% RDF (42.6%) and maize with VAM seed treatment + 75% RDF (41.4%). While, significantly lowest chlorophyll index was noticed with maize crop receiving 50% RDF and VAM seed treatment (33.5%). Gangawar (2009) reported that the seed indicated confirming the results of Etukudo *et al.* (2015). Steven *et al.* (2002) reported that the stem girth at 7th node at harvest recorded significantly higher in maize crop with VAM top dressing + RDF (8.5 cm) and was intern found to be at par with maize crop receiving VAM seed treatment + RDF (Control) only (8.3 cm). Significantly lowest stem girth was recorded maize receiving 50% RDF and VAM seed treatment and was on par with 75% RDF + VAM seed treatment (7.8 cm).

The leaf area index recorded significantly higher with maize receiving VAM top dressing + RDF (9.00) and was found to be on par with maize receiving VAM seed treatment + RDF (8.73), maize with RDF (Control) only (8.39) and maize with VAM top dressing + 75% RDF (8.22). While, significantly lowest leaf area index were resulted in maize crop receiving 50% RDF + VAM seed treatment (6.27) and was at par with maize received with VAM top dressing + 50% RDF (6.86).

Effect of VAM on yield attributes of maize

The yield attributes i.e. cob length & girth, kernel rows & number, single cob weight, shelling percentage and 1000 grain weight did not vary significantly with different VAM treatment under test except grain weight/cob and unfilled tip portion of cob differed significantly with different VAM treatments (Table 3).

However, comparison among different treatment under test indicated that cob length was higher in maize receiving VAM top dressing + RDF (8.6 cm) followed by maize received VAM top dressing + 75% RDF. While the cob girth recorded higher with VAM top dressing + RDF (17 cm) followed by VAM seed treatment + RDF

Table 2. Effect of VAM on growth parameters of maize (DHM 117) crop

Treatments	Plant height (cm) at harvest	Ear eight (cm) at harvest	Mean leaf no./plant at 60 DAS	Mean leaf area of flag leaf (cm^2) at 60 DAS	Chlorophyll index (%) at 60 DAS	Mean stem girth at 7th node at harvest (cm)	Dry matter g/m^2 at 60 DAS	Leaf area index (ratio) at 60 DAS
T1: VAM seed treatment + RDF	234.6	101.4	15.7	833.7	44.8	8.4	1274	8.73
T2: VAM seed treatment + 75% RDF	223.7	100.2	15.3	779.0	41.4	7.8	1161	7.98
T3: VAM seed treatment + 50% RDF	218.3	95.7	14.7	640.0	33.5	7.4	1069	6.27
T4: VAM Topdressing + RDF	234.7	102.2	15.7	859.7	46.8	8.5	1294	9.00
T5: VAM Topdressing + 75% RDF	226.7	101.7	15.3	805.7	43.5	8.3	1214	8.22
T6: VAM Topdressing + 50% RDF	221.3	100.4	15.3	672.7	42.6	7.9	1127	6.86
T7: Control (RDF)	222.3	100.7	15.3	822.7	44.8	8.3	1176	8.39
C.D (0.05)	NS	NS	NS	85.5	6.3	0.48	NS	-
S.Em+	6.0	2.6	0.3	27.4	2.0	0.2	11.7	-
C.V(%)	4.6	4.5	3.8	6.2	8.2	3.3	11.4	-

Table 3. Effect of VAM on yield attributes of maize (DHM 117) crop

Treatment No	Cob length (cm)	Un filled tip portion of cob (cm)	Cob girth (cm)	Kernel rows	No.of kernels/ rows	Single cob weight (g)	Grain weight (g) /cob	Shelling (%)	1000 grain wt (g)
T1: VAM seed treatment + RDF	17.9	2.8	16.9	14.5	36.1	210	170	81.3	346.7
T2: VAM seed treatment + 75% RDF	17.4	2.9	16.7	14.0	35.5	200	157	78.9	340
T3: VAM seed treatment + 50% RDF	16.9	3.1	16.1	13.5	33.5	182	137	75.5	323.3
T4: VAM Topdressing + RDF	18.6	2.1	17.0	14.7	37.6	231	192	83.4	363.3
T5: VAM Topdressing + 75% RDF	18.4	2.5	16.8	14.4	36.9	220	176	80.1	343.3
T6: VAM Topdressing + 50% RDF	17.3	2.6	16.5	13.6	36.7	199	163	81.8	333.3
T7: Control (RDF)	17.5	3.0	16.8	14.3	35.3	210	168	80.8	343.3
C.D (0.05)	NS	0.59	NS	NS	NS	NS	26.6	NS	NS
S.Em+	0.6	0.2	0.3	0.3	1.6	10.3	8.5	3.3	9.0
C.V(%)	6.1	12.2	2.6	3.6	7.5	8.6	8.9	7.0	4.6

(16.9 cm). Kernel rows noticed to be higher in maize receiving VAM topdressing + RDF (14.7 cm) followed by VAM seed treatment + RDF (14.5 cm). The No. of kernels /cob recorded higher in VAM top dressing + RDF (37.6) followed by VAM top dressing + 75% RDF (36.9). The single cob weight resulted in higher weight in cob receiving VAM top dressing + RDF (231 g) followed by maize received VAM top dressing + 75% RDF (220 g). The shelling percentage and 1000 grain weight were also resulted higher with maize received with VAM top dressing + RDF followed maize received VAM seed treatment + RDF (Table 3).

The grain weight /cob differed significantly with different VAM treatments. Significantly higher grain weight /cob recorded in maize crop received with VAM top dressing + RDF (192 g) and was on par with maize received with VAM top dressing + 75% RDF (176 g), VAM seed treatment + RDF (170 g) and maize with only RDF (Control) only (168 g). Significantly lowest grain weight /cob resulted in maize crop received with 50% RDF + VAM seed treatment (137 g) and was on par with VAM seed treatment + 75% RDF (157 g) and VAM top dressing + 50% RDF (163 g).

The unfilled tip portion of cob was significantly lowest in maize received with VAM top dressing + RDF (2.1 cm) and was on par with all VAM top dressing treatments at any fertilization. This indicates that VAM top dressing reduces the unfilled tip portion of cob.

Effect of VAM on cob & grain yield of maize

Cob yield

The cob yield recorded significantly higher in maize crop applied with VAM top dressing + RDF (11278 kg/ ha) and was on par with maize received with VAM seed treatment + RDF (10836 kg/ha), maize with RDF (Control) only (10612 kg/ha) and maize with VAM top dressing +75% RDF (10450 kg/ha). (Table 4) Significantly lowest cob yield was recorded with VAM seed treatment + 50% RDF (9115 kg/ha) and was on par with 50% RDF + VAM top dressing (6362 kg/ha).

Grain yield

The similar trend was observed for grain yield. It was significantly higher with VAM top dressing + RDF (8958 kg/ha) and was found to be at par with VAM seed treatment + RDF (8564 kg/ha), VAM top dressing + 75 RDF (8542 kg/ha) and maize with only RDF application i.e. control (8388 kg/ha). Significantly lowest grain yield was recorded with maize crop with 50% REF and VAM

Table 4. Effect of VAM on cob & grain yield of maize (DHM 117) crop

Treatments	Cob yield (kg/ha)	Grain yield (kg/ha)	B:C ratio
T1: VAM seed treatment + RDF	10836	8564	2.80
T2: VAM seed treatment + 75% RDF	10382	8295	2.75
T3: VAM seed treatment + 50% RDF	9115	7021	2.38
T4: VAM Topdressing + RDF	11278	8958	2.91
T5: VAM Topdressing + 75% RDF	10450	8542	2.81
T6: VAM Topdressing + 50% RDF	9392	7440	2.48
T7: Control (RDF)	10612	8388	2.78
C.D (0.05)	873	648	-
S.Em+	280	208	-
C.V(%)	4.7	4.4	-

seed treatment (7021 kg/ha) and VAM top dressing + 50% RDF (7440 kg/ha) which were found to be at par with each other. Sajedi and Madoni 2006 also reported that mycorrhza increased maize yield in both the conditions of optimum irrigation and in condition of water digit than treatment of without mycorrhza. The percent increase in grain yield of maize with VAM top dressing + RDF was 6.4% as compared to maize with RDF (Control) only, 21.6% as compared to VAM seed treatment + 50% RDF and 17% over VAM top dressing + 50% RDF. The mycorrhiza inoculation and the complementary use of organ mineral and inorganic fertilizer are very essential for enhancing crop yield (Mobaesea and Tavossol, 2013 sin gal of at 2012). In terms of B:C ratio, the maize with VAM top dressing + RDF has recorded higher B:C ratio (2.91) followed by VAM topdressing + 75% RDF (2.81) and VAM seed treatment + RDF (2.80).

The increase in cob and grain yield of maize with VAM top dressing + RDF, VAM seed treatment + RDF, VAM top dressing + 75% RDF & maize with RDF only may be attributed to the increase in yield attributes in general & in particular, the grain weight /cob & reduction of unfilled tip portion of cob & also to the increase in growth parameters particularly increase in chlorophyll index, leaf area of flag leaf, leaf area index & stem girth. These results are in confirmation with earlier studies by Howler *et at.* (1987), Osonubi *et al.* (1991) and Fagbila *et al.* (1998). Tas (2014) also reported a higher yield for sweet corn inoculated with mycorrhiza inoculated plants which underscores the positive effects of VAM in plant nutrition.

The increase in cob & grain yield of maize with VAM top dressing + RDF, VAM seed treatment + RDF, VAM top dressing + 75% RDF maize with RDF only may also be attributed to the initial soil fertility status which was found to be medium in organic carbon and also available NPK were also found to be medium in status which must have in turn contributed to higher nutrient uptake and resulted in higher yields in these treatments. The reliant of plant nutrition, especially phosphorus uptake by VAM have been well documented (Shratha, 2000; Boas, 2008).

In conclusion, the cob and grain yield of maize (DHM 117) was significantly higher with application of VAM top dressing + RDF and was on par with VAM seed treatment + RDF, VAM top dressing + 75% RDF & RDF control plot. From the economic & soil health point of view, the application of VAM top dressing + RDF, followed by VAM seed treatment + RDF, VAM top dressing + 75% RDF can be a suitable option without any reduction in yield significantly & statistically and also for getting higher benefit to cost ratio.

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Management of turcicum leaf blight and common rust of maize

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ABSTRACT

The crop is affected by number of fungal diseases of which turcicum leaf blight caused by *Exserohilum turcicum* (Pass.) Leo. & Suggs. and common rust caused by *Puccinia sorghi* Schw. are some of the important diseases affecting photosynthesis with severe reduction in grain yield to an extent of 28 to 91 per cent. Two years field trials on fungicidal evaluation were conducted at Agricultural Research Station, Arabhavi, University of Agricultural Sciences Dharwad, Karnataka, India from 2013 to 2014 *Kharif* under irrigated conditions. Azoxystrobin 18.2 + Cyperconazole 7.3 @ 0.125% treated plots were significantly superior over other treatments in reducing the turcicum leaf blight disease (16.6 and 13.33 PDI in 2013 & 2014 respectively) and recorded highest grain yield (62.9 and 34.74q/ha in 2013 & 2014 respectively) followed by Azoxystrobin 18.2 + Cyperconazole 7.3 @ 0.1% and these were at par with each other. Next best fungicide was 23 SC @ 0.1% which recorded turcicum blight of 27.4 and 33.33 PDI in with grain yield of 61.1 and 26.41 q/ha in 2013 and 2014. Azoxystrobin 18.2 + Cyperconazole 7.3 @ 0.1% & 0.125% and 23 SC @ 0.1% were effective in significantly reducing common rust incidence. However, all other tested fungicides were numerically superior in reducing the disease and significantly superior over untreated check in recording grain yield. In another experiment, six fungicides were tested along with control. Tebuconazole @ 0.05% and difenconazole @ 0.1% were recorded less TLB of 26.67% and 33.33% respectively. Amistar and tebuconazole @ 0.05% recorded low rust of 20.00% and 23.33% respectively. However, the highest grain yield were recorded in the treatments difenconazole @ 0.1% and tebuconazole @ 0.05% with 30.72q/ha and 29.85q/ha respectively. All the treatments except amistar @0.05% were significantly superior over control.

Keywords: Common rust, Disease, Fungicides, PDI, Turcicum leaf blight

Maize is affected by number of fungal diseases of which turcicum leaf blight caused by *Exserohilum turcicum* (Pass.) Leo. & Suggs. is one of the important diseases affecting photosynthesis with severe reduction in grain yield to an extent of 28 to 91 per cent. Disease symptoms first appear on the leaves at any stage of plant growth, but usually at or after anthesis. Another important foliar disease is common rust caused by *Puccinia sorghi* Schw. *P. sorghi* is characterized by the presence of golden-brown to cinnamon-brown pustules (uredinial) that can develop on any above-ground plant part including leaves, husks, tassels and stalks. The extent of loss due to this disease is the tune of 20-70 per cent. Yield loss by TLB and common rust diseases under experimental condition in susceptible cultivars of maize was 66.0 % and 32.0 % respectively. Turcicum leaf blight (*Exserohilum turcicum*) disease is distributed in Jammu & Kashmir, Himachal Pradesh, Sikkim, West Bengal, Meghalaya, Tripura, Assam, Uttar Pradesh, Uttarakhand, Bihar, Madhya Pradesh, Gujarat, and Tamil Nadu. Common rust disease appears mainly in peninsular India (Andhra Pradesh, Karnataka and Tamil Nadu). TLB and common rust is generally controlled with the use of disease-resistant hybrids on maize, and by foliar application of fungicides.

MATERIALS AND METHODS

Two separate experiments were conducted at Agricultural Research Station, Arabhavi, University of Agricultural Sciences Dharwad, Karnataka, India under irrigated conditions. Two years field trials (from 2013 to 2014 *Kharif*) on eight fungicidal evaluation were conducted with plot size of six rows and five meter length was maintained for each treatment with three replications

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in Randomized Block Design. In 2013, Bio Seed maize hybrid (Rajkumar) and in 2014 inbreed line G 25 (Renuka) were used. In another experiment, during 2014 *kharif* six fungicides were used on inbreed line G 25 (Renuka) with plot size of six rows and five meter length was maintained for each treatment with three replications in Randomized Block Design during the year *kharif* 2014. For both the experiments all the agronomical practices were adopted to get good crop stand. At 30 days after sowing previous year turcicum infected leaves were powdered and same has been put in the whorls of each plant to create sufficient disease pressure. First sprays of different fungicides were given at 45 DAS and second spray was give at 65 DAS. Turcicum blight and common rust diseases observations were made at 85 DAS. Later, percent disease index (PDI) was calculated and then grain yield was also recorded.

RESULTS AND DISCUSSION

The combination product Azoxystrobin 18.2 + Cyperconazole 7.3 @ 0.125% treated plot was significantly superior over other treatmnents in reducing the turcicum leaf blight disease (16.6 and 13.33 PDI in 2013 & 2014 respectively) and recorded highest grain yield (62.9 and 34.74 q/ha in 2013 & 2014 respectively) followed by Azoxystrobin 18.2 + Cyperconazole 7.3 @ 0.1% and these were at par with each other. Next best fungicide was 23 SC @ 0.1% which was recorded turcicum blight of 27.4 and 33.33 PDI in 2013 & 2014 respectively. Grain yield was 61.1 and 26.41 q/ha in 2013 & 2014 respectively (Table 1). Cyperconazole 100 SL @ 0.08%, Mancozeb 75 WP @ 0.265% and Zineb 75 WP @ 0.265 were comparatively less effective in managing the disease. Azoxystrobin 18.2 + Cyperconazole 7.3 @ 0.1% & 0.125% and 23 SC (@ 0.1% were effective in significantly reducing common rust incidence (Table 1). However, all other tested fungicides were numerically superior in reducing the disease and significantly superior over untreated check in recording grain yield (Table 1).

In another experiment, six fungicides were tested along with control. Tebuconazole @ 0.05% and difenconazole @ 0.1% recorded less TLB of 26.67% and 33.33% respectively. Azoxystrobin and tebuconazole @ 0.05% recorded lower PDI of common rust of 20.00% and 23.33% respectively. However, highest grain yield was recorded in the treatments difenconazole @ 0.1% and tebuconazole @ 0.05% with 30.72 q/ha and 29.85 q/ ha respectively. All the treatments except azoxystrobin @0.05% were significantly superior over control (Table 2).

Similarly, Harlapur (2005) observed carboxin powder seed treatment (2 g kg^{-1}) followed by two sprays of mancozeb (0.25 %) resulting in significantly minimum TLB and maximum grain yield. The effectiveness of fungicides mancozeb, propiconazole and carboxin against *Exserohilum turcicum* has been reported by earlier workers Singh and Gupta (2000) and Patil *et al*., (2000) in maize. Pandurangegowda *et al.,* (1993) reported that the foliar spray with mancozeb 0.25% three times at 10 day interval was found to be more effective and significantly reduced TLB severity and increased grain yield. Kumar *et al.*, (1977) and Kachapur and Hegde (1988) have reported that maneb followed by mancozeb effective in controlling TLB of maize. Reddy *et.al.*, (2013)

Table 1. Evaluation of fungicides over the years against turcicum leaf blight of maize

Treatments	Dosage ml or gm/lit. of water	Turcicum leaf blight disease incidence		Yield(q/ha)	
		2013	2014	2013	2014
Untreated Check	-	40.2 (39.2)	46.67 (43.06)	51.1	24.80
Amistar Xtra 280 SC (18.2 + Cyperconazole 7.3)	0.75	26.1(30.2)	36.67 (37.21)	59.6	30.10
Amistar Xtra 280 SC (18.2 + Cyperconazole 7.3)	1.00	17.1(24.2)	16.67 (23.85)	62.3	34.09
Amistar Xtra 280 SC (18.2 + Cyperconazole 7.3)	1.25	16.6(22.9)	13.33 (21.14)	62.9	34.74
Amistar Xtra 280 SC (Azoxystrobin 18.2 + Cyperconazole 7.3)	2.50	15.2(21.8)	23.33 (28.77)	62.5	32.23
Azoxystrobin 23 SC (Amistar 25 SC)	1.00	27.4(27.1)	33.33 (35.20)	61.1	26.41
Cyperconazole 100 SL	0.80	29.1(28.2)	36.67 (37.21)	59.9	23.68
Mancozeb 75 WP	2.65	30.2(33.3)	43.33 (41.14)	56.7	25.55
Zineb 75 WP	2.65	32.1(34.6)	43.33 (41.14)	55.9	25.18
SEm ±		**0.83**	**2.26**	**0.31**	**0.85**
CD @ 5 %		**2.55**	**6.78**	**1.12**	**2.56**

Table 2. Evaluation of fungicides against common rust of maize (K-2014)

Treatments	Dosage ml or gm/ lit. of water	Common rust incidence	Yield (q/ha)
Untreated Check	-	36.67(37.21)	24.80
Amistar Xtra 280 SC (Azoxystrobin 18.2 + Cyperconazole 7.3)	0.75	20.00 (26.06)	30.10
Amistar Xtra 280 SC (Azoxystrobin 18.2 + Cyperconazole 7.3)	1.00	16.67 (23.85)	34.09
Amistar Xtra 280 SC (Azoxystrobin 18.2 + Cyperconazole 7.3)	1.25	23.33 (28.27)	34.74
Amistar Xtra 280 SC (Azoxystrobin 18.2 + Cyperconazole 7.3)	2.50	16.67 (23.85)	32.23
Azoxystrobin 23SC (Amistar 25 SC)	1.00	26.67 (30.98)	26.41
Cyperconazole 100 SL	0.80	26.67 (30.98)	23.68
Mancozeb 75 WP	2.67	33.33 (35.20)	25.55
Zineb 75 WP	2.67	30.42 (33.46)	25.18
SE m ±		**2.81**	**0.85**
CD @ 5 %		**8.41**	**2.56**

Table 3. Management of turcicum leaf blight and rust diseases through chemicals (K-2014)

Treatments	Dose (ml or g/liter)	PDI (%)		Yield (q/ha)
		TLB	Rust	
Difenconazole	1.0 ml	33.33 (35.20)	30.00 (33.20)	30.72
Hexaconazole	1.0 ml	43.33 (41.14)	30.00 (33.20)	26.39
Tebuconazole	0.5ml	26.66 (30.98)	23.33 (28.77)	29.85
Propiconazole	1.0 ml	40.00 (39.22)	30.00 (32.99)	28.32
Trifloxystrobin 25% + Tebuconazole 90% WP	0.5 g	40.00(39.22)	26.66 (30.98)	28.16
	0.5 ml	40.00 (39.22)	20.00 (26.55)	22.44
Untreated check	-	43.33 (41.44)	43.33 (41.44)	19.63
SEm±		**1.61**	**2.09**	**1.12**
CD (p=0.05)		**4.97**	**6.44**	**3.44**

reported that mancozeb @ 0.25% and combination product carbendazim + mancozeb recorded lowest PDI of TLB. Next best was metriram+pyraclostrobin in reducing the disease followed by propiconazole.

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Assessment of yield loss due to sorghum downy mildew in maize

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ABSTRACT

Sorghum downy mildew has long been recognized as a destructive disease on maize and sorghum, throughout the world. The disease caused by *Peronosclerospora sorghi*. The impact of SDM in maize on yield and yield parameters were assessed under field conditions by using genotype CM 500, a known susceptible check and a resistant check Hema. In unprotected treatment, the mean SDM incidence in maize was recorded maximum (98.0%) in local susceptible genotype (CM 500), while it was 10 per cent in Hema. However, these same genotypes expressed their complete resistance to the disease under the protected conditions. The yield and yield attributes like plant height, ear height, fresh ear weight, seed/grain weight and test weight were also found significantly higher in Hema hybrid under protected and unprotected conditions. However, in CM 500 these attributes are also good under protected conditions but in case of unprotected conditions the expressions of these parameters were very poor.

Keywords: Maize, Peronosclerospora sorghi, Sorghum downy mildew, Yield loss

Maize (*Zea mays* L.) holds a unique position in world agriculture as a food, feed and industrial crop par its excellence. Maize is the third most important food grain in India after wheat and rice. Maize cultivation became revolutionized across the globe and it is replacing wheat with 27.65 per cent of total cultivated area. Globally the average productivity of maize is 49.28 q/ha. However, the highest productivity is in USA (85.78 q/ha) followed by China (Anon., 2013).

In developing countries, maize is not only an important human nutrient, but also used as a basic element in animal feed. In Latin America and Africa, it is the staple food, while in Asia, it is used for food and animal feed. Globally, it has been estimated that approximately 21 per cent of the total grain produced is consumed as food (Anon., 2013). In India, Maize is cultivated in the states of Gujarat, Bihar, Andhra Pradesh, Madhya Pradesh, Rajasthan, Chhattisgarh, Karnataka, Maharashtra, Tamil Nadu and Uttar Pradesh. Karnataka is one of the major maize producing state in the country. During 2012-13, maize was grown over an area of 13.76 lakh hectares with a production of 47.50 lakh tonnes. The productivity of the state was 38.50 quintals per ha. Karnataka accounts for six per cent of the total maize area with 12 per cent production share in the country (DMR, 2013).

Sorghum downy mildew in maize caused by an oomycete *Peronosclerospora sorghi*(Weston and Uppal) Shaw has become severe threat for the sustainable maize cultivation (Gowda *et al.*, 1989). The downy mildews are the old world diseases causing enormous losses in crop plants including maize. Twenty one species of downy mildew fungal pathogens have been reported to attack the family Poaceae, of which 10 species in three fungal genera have been reported to cause different downy mildews in maize (Nair *et al.*, 2004).

Among the downy mildews, sorghum downy mildew (SDM) in maize caused by P. sorghi is one of the important diseases due to its deleterious effect on successful production of maize across the globe. The SDM is particularly prevalent in the peninsular India, Karnataka, Tamil Nadu and Andhra Pradesh. The disease is causing yield loss up to 100 per cent in the places where the disease would occur at the seedling stage (Anon., 2013).

Sorghum downy mildew poses a continuing threat to successful maize production and also ruining the financial

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status of several industries. Its effect on the yield and yield parameters were studied here to know how much yield loss it can cause under epiphytotic situations.

MATERIALS AND METHODS

The impact of SDM in maize on yield and yield parameters were assessed under field conditions. The experiment was conducted in RCBD design (Randomized completely block design) with two treatments T1: Protected (Seed treatment with Ridomil MZ @ 2 gm/kg seed + Foliar application of Ridomil MZ @ 4 gm/lit and T2: Unprotected (Control i.e. no seed treatment) and 13 replications of each treatments. The locally available hybrid Hema, a resistant hybrid developed by UASB was used as a resistant check along with one inbred developed and maintained at ZARS, V. C. Farm, Mandya. The seeds of Hema a promising resistant hybrid developed by UAS Bangalore for sorghum downy mildew, Turcicum leaf blight and Polysora rust in maize. The genotype CM 500 is a known susceptible line for sorghum downy mildew in maize.

The experiment was conducted in two *kharif* seasons (2012 and 2013). The seeds of these cultivars were collected from the AICRP, Maize, VC Farm Mandya. The hybrid and inbred was used in the study, the seeds of these seeds were treated with Ridomil MZ (Metalaxyl) @ 2 gm/kg basis for one treatment. However, the seeds soaked in sterile water were used for the sowing in case of unprotected treatment. After 5 days of sowing, the artificial inoculation with the P. sorghi was done for both the treatments. The inoculation was continued for a period of 7 days. However, after 20 days of sowing, the foliar application of protected treatment Ridomil MZ @ 4 gm/ lit of water in order to avoid the disease.

The observations on the parameters like disease incidence, yield and yield contributing characters like plant stand in each treatment, plant height, ear height, ear length, number of ear rows, number of grains per row and total grain weight were recorded on five randomly tagged competitive plants per replication in each genotype. The mean of these five plants were used as the mean of the entry in the statistical analysis, of all the replications.

RESULTS AND DISCUSSION

The mean sorghum downy mildew incidence in maize was recorded maximum (98 %) in local susceptible cultivar (CM 500) during *kharif* 2012 and 2013 under artificial inoculation where no control measures were taken place. However, there was 20.0 per cent disease incidence on the same cultivar which was protected by using Ridomil MZ at 2 g/kg seed as seed treatment and as a foliar spray with Ridomil MZ 4g/lit of water at 40 days after sowing. Moreover, the local public hybrid (Hema) was recorded less incidence (10%) in which no control measures were taken place. But, the same hybrid showed very less incidence (3.75%) to sorghum downy mildew under protected condition (Table 1). These results were is in accordance with the results of Sangam *et al.* (1999). They reported that, Metalaxyl slurry treatment at 4 g/kg significantly checked the disease up to 30 days after planting. In plots planted withVL-54 and Ganga 5 seeds treated with 4 g/ kg metalaxyl slurry, disease intensity was significantly reduced for 30 days after planting.

Plant and ear height

The plant and ear height was recorded in both protected and unprotected condition for CM 500 and Hema (Table 2). In protected condition, the plant height and ear height for Hema were 192 cm and 145 cm, respectively whereas, for CM 500 it was 185 cm and 130 cm for plant and ear height, respectively. However, in unprotected condition the plant height and ear height for Hema were 180 cm and 140 cm respectively and for CM

Table 1. Sorghum downy mildew incidence in unprotected and protected treatments in yield loss assessment studies

		Avg Pl Stand		SDM		
Treatment/s	Genotype	Total plants	No. of infected plants	2012	2013	MEAN
Unprotected						
	CM 500	80	78	96.00 (9.85)	100.00 (10.02)	98.00 (9.85)
	HEMA	80	08	9.00 (2.04)	11.00 (2.08)	10.00 (1.08)
Protected						
	CM 500	80	14	17.50 (2.36)	22.50 (5.87)	20.00 (4.97)
	HEMA	80	03	3.75 (1.03)	3.75 (1.03)	3.75 (1.03)
	SE.M±			2.41	2.75	2.25
	CD @ 5%			6.58	8.35	6.28

Table 2. Effect of sorghum downy mildew on grain yield and yield attributes in maize

	Genotype	Plant height (cm)	Ear height (cm)	Cob length (cm)	FEW (kg/plot)	Grain yield (kg/plot)	% grain loss	Test weight	% loss in TW
Unprotected									
	CM 500	45.00	15.00	5.00	3.70	1.60	75.50	104	85.75
	Hema	180.00	140.00	16.00	14.20	8.10	6.50	160.6	7.25
	CM 500	185.00	130.00	15.00	11.40	6.53	0.00	147.0	0.00
Protected									
	Hema	192.00	145.00	18.00	17.80	8.67	0.00	174.7	0.00
	SE.m+	23.78	21.89	8.75	3.45	5.87	4.35	24.25	16.43
	CD @ 5%	38.75	42.38	13.45	7.85	9.65	9.33	35.46	23.21

Mean of 13 replications

500 it was 45 cm and 15 cm plant and ear height, respectively. These results were in accordance with the results of De Milliano *et al.* (1992) where they reported that sorghum downy mildew has very high potential for causing economic losses in both maize and sorghum.

Cob length

The cob length of Hema was 18 cm in protected condition and 16 cm in unprotected condition whereas, the cob length of CM 500 was 15 cm in protected condition and 5 cm in unprotected condition (Table 2). Number of kernel rows and number of kernels per row In Hema, the number of kernel rows was 18 under both protected and unprotected condition. However, number of kernels per row varied under protected (20) and unprotected conditions (12) for CM 500 cultivar (Table 2).

Fresh ear weight (FEW)

The mean FEW in CM 500 was 11.4 kg/plot in protected treatment where as in unprotected condition the FEW was 3.7 kg/plot. In Hema, the FEW were 17.8 kg/plot in protected treatment and it was 14.2 kg/plot under unprotected condition (Table 2).

Grain yield

The grain yield of CM 500 was 6.53 kg/plot where the crop was protected and 1.6 kg/plot grain yield was recorded where in crop was not protected. However, the grain yield of Hema was 8.67 kg/plot in the protected treatment and 8.1 kg/plot was observed in the unprotected treatment (Table 2).

Per cent grain yield loss due to sorghum downy mildew

In unprotected plots of susceptible cultivar (CM 500) the mean DM incidence was 98.0 per cent while in case of protected plots there was 20.0 per cent disease. In unprotected plots of Hema the disease was low (10.0 %) while protected plots recorded 3.75 per cent disease. The seed yield (kg/plot) and 1000 grain weight of Hema was significantly higher as compared to CM 500 (Table 2).

The maximum seed yield (8.67 kg/plot) and test weight (174.7 g) was recorded in protected plots of Hema. Whereas, in unprotected treatment, Hema recorded the seed yield of 8.1 kg/plot and 160.6 g test weight. However, in protected plots of CM 500, the seed yield and test weight was 6.53 kg/plot and 147.0g and in case of unprotected plots, the seed yield was 1.6 kg/plot and 104g test weight.

The maximum per cent loss in grain yield (75.5 %) was observed in unprotected plots of CM 500 which showed 98.0 per cent disease incidence as compared to 6.5 per cent grain yield loss in unprotected plots of Hema, where disease was 10.0 per cent.

However, the per cent loss in test weight (1000 seed weight) was maximum (28.6 %) in unprotected plots of CM 500 when compared to unprotected plots of Hema (8.1 %). The reductions in seed yield and test weight were directly correlated with per cent affected plants. The crop-loss estimates in genotypes of varying reaction to SDM indicated that maximum grain loss (78.6%) occurred in the highly susceptible genotype with maximum disease pressure (73.8%). The same kinds of results were also reported by Trivedi *et al*. (2006). They assessed the yield loss due to Rajasthan downy mildew in maize using susceptible cultivar (Kiran) and compared with resistant cultivar (Prabhat) under field conditions. They reported that, the yield losses were 35 per cent with the infection of 67.9 per cent in susceptible cultivar (Kiran) which was protected using fungicidal seed treatment. However, Prabhat, the resistant cultivar showed considerable yield without protection with minimal incidence of the disease.

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SHORT COMMUNICATION

Participatory maize improvement for enhancing yield and production

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Participatory plant breeding (PPB) is the process by which farmers are routinely involved in a plant breeding programme with opportunities to make decisions throughout. It involves scientists, farmers, and others, such as consumers, extensionists, vendors, industry, and rural cooperatives in plant breeding research. The primary aim of this activity is to enable tribal and farm families to initiate PPB along with scientists. In recent years there has been an increasing interest towards participatory research in general, and towards participatory plant breeding in particular. It is termed "participatory" because many actors, and especially the users, can have a research role in all major stages of the breeding and selection process. PPB is an extension of Participatory Varietal Selection (PVS)

Participatory breeding will help to convert on-farm conservation to on-farm management of agro-biodiversity. Such participatory breeding work will be linked to training in seed technology, including aspects of post-harvest technology. The project, initiated in June 1998, took into account the tribal and farm family status and environment and chose the crops for PPB in three target sites: Jeypore Tract of Orissa (rice), Wayanad district of Kerala (medicinal rice, pepper) and Kolli Hills of Tamil Nadu (minor millets). PPB provides benefits to a specific user and build farmer skill to enhance farmer selection and seed production efforts. Participatory Crop Improvement (PCI) involves farmers in different stages of selection and evaluation of future varieties, and proposes several levels of involving farmers in decision making (Sperling *et al.*, 2001). In PPB, farmers are actively involved in the breeding process, from setting goals to selecting variable, early-generation material. In PVS, farmers are given a wide range of new cultivars to test for themselves in their own fields. In our PPB programmes we have exploited the results of PVS by using identified cultivars as parents of crosses.

Need of Participatory Plant Breeding (PPB)

- To build a better ***linkage*** between users' demand and breeders' offer *(spontaneous in private breeding)*.
- To help the farmers to get a better *output* from poorly controlled cropping environments *(thanks to more diverse and locally adapted genetic material)*.
- To facilitate knowledge and know-how *sharing* between users and scientists.
- To contribute to *in situ managing* the genetic resources valuable for the local communities.

It is based on the principle of sufficient knowledge of farmers' specific production needs and of the advantages and disadvantages of the local varieties they use. When farmers are involved from the first segregating generation (F_2 or F_3) and when selection is to be carried out in their own fields, PPB should necessarily be conducted with relatively few plants. That is, the number of either crosses or plants from the F_2 generation should be smaller than that used in a conventional programme on an experiment station. Considering this limitation, some authors consider that PPB should involve a strategy that makes only a few crosses, rigorously selects parental varieties and uses a large number of plants from the F_2 generation (Witcombe and Virk, 2001). Another PPB strategy comprises population improvement methods associated with recurrent selection, using a narrow genetic base and well-selected specific germplasm. It can be applied to autogamous crops when several traits are being selected and the proportion of desired recombinations is expected to increase, thus limiting the risks of a strategy of few crosses (Witcombe and Virk, 2001). Progress from plant breeding has been slow in some marginal environments. Conventional or formal plant breeding (FPB) programs conducted by international agricultural research centres or national programs in developing countries have been criticized for ignoring indigenous germplasm, failing to breed for conditions facing poor farmers, and emphasizing selection for broad versus local adaptation.

A suite of techniques, referred to as participatory plant breeding (PPB) and including farmer-participatory or farmer-led selection, on-farm evaluation, and use of local landraces, has been advocated in response to this critique. PPB programs are diverse in scope and approach, but often rely heavily on farmer visual evaluation or phenotypic mass selection to select for simply-inherited traits, with limited replicated yield testing in multiple-environment trials (MET), one of the main tools of Conventional Plant Breeding (CPB). Prediction equations derived from selection theory can be used to examine the conditions under which idealized versions of CPB and PPB may be expected to achieve genetic progress for traits such as yield. The effectiveness of any selection environment is determined by both the genetic correlation between genotype performance in it and the target environment (r_G) and the heritability of genotypic differences in the selection environment (H_s). r_G is a measure of the accuracy with which performance of genotypes in the selection environment predict performance in the target environment; H_s a measure of precision with which performance differences among genotypes can be measured in the selection environment. In this paper we use this framework to compare FPB and PPB with respect to these determinants of selection response. Particular areas examined include: (i) selection for broad and specific adaptation; (ii) on-station versus on-farm selection; and (iii) selection under high-yield versus low-yield conditions.

In general, PPB systems attempt to maximize gains through the use of on-farm evaluation and the skills of farmer-selectors to maximize r_G. FPB exploits METs to maximize Hs. PPB is most likely to develop cultivars that out-perform the products of FPB when it is applied in low-yield cropping systems, because it is in such situations that r_G between high-yield breeding nurseries and low-yield target environments is likely to be low or negative. To make continued gains, and to compete with internationally-supported CPB programs, PPB systems will need to counter the obscuring effects of uncontrollable within-field, site-to-site, and year-to-year heterogeneity. Simple and robust designs for on-farm METs are needed for this purpose.

Modern plant breeding stands among the greatest scientific and human success stories of all time. Yet the fruits of major advances in agricultural science, such as those from the Green Revolution, have bypassed hundreds of millions of farmers in developing countries, most of whom operate small farms under unstable and difficult growing conditions. The adoption of new plant varieties by this group has been abysmally low. For years, this gap has haunted scientists, development workers, governments, donors, and all others with a stake in agricultural progress and the fight against poverty. But, beginning in the 1980's, it also stimulated the creation of a novel and promising set of research methods collectively known as participatory plant breeding (PPB).

Goal of PPB

Over the last decade, PPB has been applied as a crop improvement strategy primarily in non-commercial crops and in very unpredictable, stressed production environments. A range of other goals have also been defined within PPB programs ie., enhancing biodiversity and germplasm conservation; developing adapted germplasm for especially disadvantaged user groups (eg. women, poor farmers); making breeding programs more cost efficient, particularly through decentralization of programs which target more niches. As partners usually have to accept trade-offs in reaching certain goals, it is important at the very beginning of a PPB collaboration for those concerned scientists, farmers, development / NGO personnel- to discuss explicitly primary and secondary goals, and the minimal agreed-upon outcomes for which collaborators are aiming.

Key assumptions for PPB

- Farmers are interested in participating in plant breeding
- Farmers and scientists can successfully collaborate.
- It will not fail because:
- The parents of crosses include locally adapted material;
- Selection is in the local environment;
- Varieties are selected by farmers for the traits farmers consider important.

Types of PPB

PPB can be **consultative** and **collaborative.** The approach used will depend on the crop and the availability of resources.

Consultative

Farmers are consulted at every stage - for example, in setting the breeding objectives, choosing the appropriate parent, and by making joint selections with breeders from material grown by breeders. Hence, until there is a finished product from the breeding programme for farmers to test in PVS trials, farmers are not involved in growing material in their fields.

Collaborative

Farmers grow the variable PPB material in their own fields and select the best plants from it. Scientists can then obtain seed from farmers to test their selections in research station and participatory trials.

Steps for participatory plant breeding

1. Set the breeding objectives

- Crop-focused Participatory Rural Appraisal (PRAs)
- Analyse results of participatory varietal selection.

2. Identify the parent material

- From local landraces
- From varieties tested by PVS
- From high-yielding varieties with complementary characteristics.

3. Decide on the model (consultative/collaborative)

- On the basis of available resources
- On the basis of the crop (collaborative participation is simpler in an inbreeding crop).

4. Enter the best participatory plant breeding lines in PVS trials and facilitate their entry in normal on-station trials.
5. Prepare release proposal, if success is achieved

Possible Outcomes/Benefits of PPB

- *Production gains*: yield increases; increases in stability of yield; faster uptake; wider diffusion; and higher market value of products.
- *Biodiversity enhancement*: communities have wider access to germplasm; wider access to related knowledge; and increased inter- and intra-varietal diversity.
- *Cost-efficiencies and effectiveness*: Fewer researches dead-end; more opportunities for cost-sharing in research; and less expensive means of diffusing varieties.
- *Effective meeting of user needs*: higher degree of farmer satisfaction; broader range of users reached, including marginal farmers; and promotion of group learning through farm walks.

Advantages of participatory over conventional breeding methods

- At least one parent in any cross is well adapted to the local environment.
- Genotype x environment interactions is used positively because breeding is done in the target environment.
- The impact of genotype x year interaction is probably reduced because local parental materials have adapted to local year-to-year variations.
- Only a few crosses are made, so large F_2 and F_3 populations can be grown to increase the likelihood of selecting desirable segregants.

Participatory Plant Breeding in Maize

A case study in Gujarat describes how plant breeders and farmers worked together to produce improved varieties of maize for the low-resource farmers of the Panchmahals district of Gujarat, India. Initially, farmers tested a range of maize varieties in a participatory varietal selection (PVS) programme. However, none of these proved to be very popular with farmers, although farmers who had more fertile fields adopted the variety Shweta from Uttar Pradesh. Hence, in 1994 a participatory plant breeding (PPB) programme was begun to generate new, more appropriate varieties. Yellow- and white-endosperm maize varieties were crossed that had been either adopted to some extent following PVS or had attributes, such as very early maturity, that farmers had said were desirable. In subsequent generations, the population was improved by mass selection for traits identified by farmers. In some generations, farmers did this in populations which were grown by breeders on land rented from a farmer. Soil fertility management was lower than that normally used on the research-station. The breeding programme produced several varieties that have performed well in research-station and on-farm trials. One of them, GDRM-187, has been officially released as GM-6 for cultivation in hill areas of Gujarat state, India. It yielded 18% more than the local control in research-station trials, while being seven days earlier to silk. In farmers' fields, where average yields were lower, the yield advantage was 28% and farmers perceived GDRM 187 to have better grain quality than local landraces. PPB produced a variety that was earlier to mature than any of those produced by conventional maize breeding, and took fewer years to do so. A case in point was the maize breeding program at Pantnagar, one of the leading agricultural universities in India. On-farm research was a prime component of that program, and a routine was developed to enhance the odds that information generated in the on-farm stage would be utilized in decision-making on breeding priorities (Agarwal 1979 and Biggs 1983). In China, a project team has been established in which local farmers cooperate with the Centre for Chinese Agricultural Policy, which is part of the Chinese Academy of Sciences, and the Guangxi Maize Research Institute. The multidisciplinary research team carries out trials in six villages and on-station using both PPB and PVS experiments. The trials allow for comparison in terms of locality, approach, objectives and the types of varieties tested. Varieties include landraces, open-pollinated varieties, so-called waxy maize varieties and varieties introduced by CIMMYT. Some of the CIMMYT varieties have been locally improved through crossings and selections. Agronomic traits, yields, taste and palatability of these improved varieties are satisfactory. They are showing better adaptation to the local environments. Varietal diversity is increasing. The project team supports farmers' groups by bringing them into contact with formal system actors through training, network building and raising awareness about markets. Since the early 1990s, scientists in CAZS-NR (Centre for Arid Zone Studies) at the University of Wales, Bangor, in the United Kingdom have worked in participatory variety selection and participatory plant breeding. For PPB, they have focused on cereals, mostly rice and maize, in marginal regions of South Asia, mainly India, Nepal, and, most recently, Bangladesh. A major PPB project is being carried out in Guangxi province in south-west China and follows up on an impact study carried out from 1994 to1998 by the International Maize and Wheat Improvement Centre (CIMMYT) to assess the impact of CIMMYT's maize germplasm on poor farmers in south-west China (Yiching Song 1998). One of the key findings of the impact study was that the systematic separation between the formal and the farmers' seeds system resulted in inadequate variety development, poor adoption of formally bred modern varieties, an increasingly narrow genetic base for breeding and a decrease in genetic biodiversity in farmers' fields

Future prospects of PPB

1. PPB should take a broader approach to solve the critical problems arising out of modern agriculture such as economic viability of crop production, food and nutritional insecurity, degradation of land, destruction of biodiversity and unsustainable agricultural practices.
2. PPB should recognize and value the knowledge and important role of women in conservation of biodiversity and agriculture and should address gender imbalances in participation, decision-making and benefit sharing.
3. PPB should be based on principles that emphasis deposition of problems to be addressed, symmetrical relationships among partners and constant evaluation and monitoring of the success of participatory improvement programmes.
4. PPB should be into account farmer's gendered priorities and practices, and strive for social and gender equity in conservation.
5. Participatory breeding need to be cost-effective, work on downstream technology and breed site-specific varieties capable of sustaining production.
6. Farmers' gendered ITK and wisdom need to be recognized rewarded and incorporated in participatory initiatives.
7. Scientific analysis of PPB data should be a course of strength for farmers for making optimal decisions.
8. PPB options should not deal only with improving yield of farmers' varieties, but also provide a strategic frame for saving grains and seeds and gainful marketing, as provided in the protection of plant varieties and farmers' Right Act, 2001. Government should make it a policy to procure farmers' landraces at a remunerative price and distribute them through the Public Distribution System (PDS).
9. Participatory research has been shown to be efficient and accelerate adoption of acceptable varieties.
10. Novel genetic combinations incorporating drought and salinity resistance need to be properly programmed into participatory breeding taking care to assign proper age weight to phenotypic expression.

Most of the data on different types of farmer participation in selection suggest that there is little to lose and much to gain by involving farmers, and more generally the users, in the process of plant breeding. Decentralized-participatory plant breeding should not be seen as "an alternative" type of plant breeding somewhat opposed to the formal plant breeding, but rather as an approach to specifically address situations such as marginal environments where GE interactions are repeatable and large, precluding the adaptation of one or few varieties, or where there is a variety of different requirements (quality, crop duration, management, etc). One specific advantage of decentralized participatory plant breeding is to rapidly adapt the crops to a changing agronomic management. Eventually, PPB could be the only possible type of breeding for crops grown in remote regions, for crops for which a high level of diversity is required within the same farm, or for those crops locally important but globally considered as minor crops and therefore neglected by formal breeding. In the past, researchers have relied heavily on the extension department of the Ministry of Agriculture to transfer technologies to the farmers. Without intensive interaction with farmers in the development of maize varieties, there is a possibility of ignoring certain characteristics that would be of importance to farmers in their decision making process of whether to adopt a variety or not. "In the very poor, rain-fed rice-growing areas of South Asia that the green revolution passed by, participatory plant breeding is now paying off with strong early adoption of farmer selected varieties that provide 40 percent higher yields in farmers' fields. The approach needs to be more widely tested in the heterogeneous rain-fed environments of Africa, where involving farmers, especially women farmers, in selecting varieties has shown early successes for beans, maize and rice. The cost effectiveness of the approach for wider use also needs to be evaluated."

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Aim and Scope

The Maize Journal publishes peer-reviewed original research papers, short communications and critical reviews in English on all aspects of maize research and related industries (starch, oil, protein, alcoholic beverages, food sweeteners and bio-fuel, *etc.)* from around the globe. The Maize Journal is published half yearly by the Maize Technologists Association of India (MTAI). All contributions to this Journal are peer reviewed and published free of charge.

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Rice, K. (1992). Theory and conceptual issues. In: Gall, G.A.E. and Staton, M. (Eds.), Integrating Conservation Biology and Agricultural Production. Agriculture, Ecosystems and Environment. 42: 9-26.

c. *For books*

Gaugh, Jr., H.G. (1992). Statistical Analysis of Regional Yield Trials. Elsevier, Amsterdam.

d. *For multi-author books*

DeLacy, I.H., Cooper, M. and Lawrence, P.K. (1990). Pattern analysis over years of regional variety trials: relationship among sites. In: Kang, M.S. (Ed.), Genotype by Environment Interaction and Plant Breeding. Louisiana State University, Baton Rouge, LA, pp. 189-213.

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LANDMARK PAPERS OF MAIZE RESEARCH IN 2015

S.No	Paper	Journal Impact Factor	Key Finding
1	Nuccio *et al*. (2015). **Expression of trehalose-6-phosphate phosphatase in maize ears improves yield in well-watered and drought conditions.** *Nature Biotechnology* 33: 862-869	41.51	The study reveals an effective way of minimising the negative impact of drought stress on the maize grain yield by altering the sucrose metabolism in the developing maize ears.
2	Kurti and Holland (2015). **New insight into a complex plant–fungal pathogen interaction.** *Nature Genetics* 47: 101-103	29.35	Reports the identification of a maize wall-associated kinase gene *ZmWAK*, conferring quantitative resistance to maize head smut, not by preventing initial infection but by limiting its spread through the plant.
3	Bousios *et al*. (2015). **A role for palindromic structures in the cis-region of maize Sirevirus LTRs in transposable element evolution and host epigenetic response.** *Genome Research* (Accepted manuscript, published online in advance).	14.63	Provides crucial insights into the mechanism of siRNA mediated TE silencing in the host. Pallindromic sequences, along the length of TE, have been shown to be responsible for influencing the transposition potential, siRNA targeting level and ultimately the fate of an element within the genome.
4	Li and Yan (2015). **Dissecting meiotic recombination based on tetrad analysis by single-microspore sequencing in maize.** *Nature Communications* 6:6648	11.47	Describes a simple method to isolate and sequence the whole genome of each of the four microspores from a single maize tetrad, to facilitate the recombination studies at the single-cell level.
5	Erb and Veyrat (2015). **Indole is an essential herbivore-induced volatile priming signal in maize.** *Nature Communications* 6:6273	11.47	The study affirms the importance of HIPVs in plant-plant communications during herbivore insect infestation. It further characterizes indole as a potent aerial priming agent that prepares systemic tissues and neighbouring plants for subsequent attacks.
6	Mao *et al*. (2015). **A transposable element in a NAC gene is associated with drought tolerance in maize seedlings.** *Nature Communications* 6:8326	11.47	Provides insight into the genetic basis for natural variation in maize drought tolerance, which may have implications towards improving this trait in cultivated germplasm.
7	Lu *et al*. (2015). **High-resolution genetic mapping of maize pan-genome sequence anchors.** *Nature Communications* 6:6914	11.47	Unravels an effective mapping approach to map millions of high quality sequence anchors for maize pan-genome, essential for complete understanding of the genetic control of phenotypes.
8	Dell'Acqua *et al*. (2015). **Genetic properties of the MAGIC maize population: a new platform for high definition QTL mapping in *Zea mays*.** *Genome Biology* 16:167	10.81	Demonstrates first balanced multi-parental maize population, offering high diversity and dense recombination events, which could be instrumental in improving our understanding of the genetic basis of various quantitative traits.
9	Baute *et al*. (2015). **Correlation analysis of the transcriptome of growing leaves with mature leaf parameters in a maize RIL population.** *Genome Biology* 16:168	10.81	A novel strategy, which employs transcriptomic studies along with detailed analysis of leaf growth dynamics, to unravel the molecular networks underlying the leaf growth in maize.
10	Zhaia *et al*. (2015). **Spatiotemporally dynamic, cell-type–dependent premeiotic and meiotic phasiRNAs in maize anthers.** *PNAS* 112(10): 3146-3151	9.67	Identifies two distinct classes of maize phasiRNAs exhibiting spatiotemporal regulation of tapetal cell differentiation, thereby impacting male fertility.
11	Sidhu *et al*. (2015). **Recombination patterns in maize reveal limits to crossover homeostasis.** *PNAS* 112(52): 15982-15987	9.67	Reports a less robust meiotic crossover control mechanism in maize, which may provide clues on how to manipulate recombination rates for maize plant breeding.
12	Bermudez *et al*. (2015). **A MYB/ZML Complex Regulates Wound-Induced Lignin Genes in Maize.** *The Plant Cell* 27(11): 3245-3259	9.34	Sheds light on a molecular mechanism involving a MYB/ZML complex in which wound-induced lignification can be achieved by the de-repression of a set of lignin genes.

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